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# Metal Progress

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# Weldability of Steel

*Three interesting communications, printed below, comment on Martin Seyt's review of current opinion about "weldability", and its simple relationship to hardenability. The last contribution swings as far on the other side, with a systematic presentation of numerous other factors that influence the entire joint as a part of a serviceable structure*

## Deviations in Predicted Weldability by Lehigh and Rensselaer Systems

By Daniel Rosenthal
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IN *Metal Progress* for February, Martin Seyt outlines the work done at Lehigh and at Rensselaer, and finds that these two studies predict the same welding conditions for a joint of assumed geometry. While agreement will always be good, I wouldn't expect, in general, identical results when using the two systems.

Before going into details, it is well to point out that, whatever discrepancy there is between the two systems, this discrepancy is due to a difference not in principles but in methods of measurement.

It will be recalled that both studies developed a relation between the rate of cooling near the weld and the welding conditions as defined by energy input, welding speed, and joint geometry. But whereas in the Rensselaer system the rate of cooling is measured directly by means of thermocouples, in the Lehigh system the rate of cooling is expressed by a position on the Jominy hardenability bar. This last procedure is entirely legitimate, since each distance from the end of the Jominy bar is known to correspond to a definite cooling rate, covering the range between water quench and air cool. However, the relation between distance from the end and critical cooling rate is far from being linear; in fact, the rate of cooling and the distance on the Jominy bar vary in a converse fashion. As a result, moderately high rates of cooling, for instance between 40 and 120° F. per sec., can be located with a reasonable degree of accuracy, whereas the exact location of such low rates of cooling as less than 20° F. per sec. is more difficult to estimate.

This difficulty does not exist when using thermocouples, since low rates of cooling can be measured even more accurately than higher rates of cooling.

Therefore, whatever discrepancy there is

between the two systems, low rates of cooling are likely to accentuate it. This means that greater discrepancy is to be expected with higher preheat, since the purpose of preheat is to lower the rate of cooling.

On the other hand, the Lehigh system oversimplifies the welding conditions by assuming that the two factors, geometry and preheating, are independent. Evidence to the contrary is given in the Appendix to the article published by the author in *Welding Research Supplement*, Vol. 23, February 1944, page 92-s.

On the basis of the foregoing general remarks, one may ask, "What is the maximum expected discrepancy between the two systems?" This is best answered by comparing the energy inputs tabulated by the two systems as a function of the rate of cooling — or, what amounts to the same thing, the corresponding distance on the Jominy bar. To make such a comparison possible at low rates of cooling, the data in the table at the bottom of this column are limited to ½-in. and ¼-in. plates, welded with a 400° F. preheat. It is apparent from these extreme examples that the difference in the two systems may reach, exceptionally, a value of 20%.

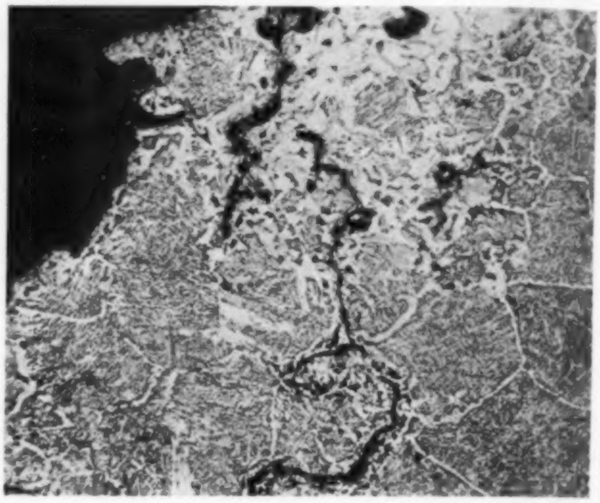
To conclude, it will be remembered that the present discussion has been limited to the problem of predicting rates of cooling from known welding conditions. The problem of predicting hardness and ductility, which after all is the main object of the two systems, is still dependent on how completely the mechanical properties of the metal adjacent to the weld are determined by the rate of cooling in the critical range of transformation of austenite. Experiments performed at Lehigh and at Rensselaer on a variety of carbon and low alloy steels seem to indicate that the prediction of mechanical properties can be carried out in a quite satisfactory manner for this category of steels on the basis of the rate of cooling alone. Whether the latter criterion is still sufficient when dealing with other steels can only be answered by a direct verification.

**Table I — Comparison of Rensselaer and Lehigh Systems for a 400° F. Preheat**

Speed of Welding: 6 in. per min.

| Cooling Rate at 1300° F. °F. per Sec. | Corresponding Jominy Distance in $\frac{1}{16}$ in. | Energy Input, Kilowatts | | | |
|---|---|---|---|---|---|
| | | ½-in. Plate | | ¼-in. Plate | |
| | | Rensselaer | Lehigh | Rensselaer | Lehigh |
| 40 | 7 | 3.78 | 3.6 | 1.62 | 1.8 |
| 35 | 7.8 | 4.0 | 4.3 | 1.74 | 2.15 |
| 20 | 10.5 | 5.05 | 6.0 | 2.37 | 3.0 |
| 10 | 15 | 7.5 | 8.5 | 3.75 | 4.25 |

*Fig. 1 — Etched Section in Base Metal Near Weld That Developed "Hot Cracks". The defect follows the austenitic grain boundaries, and is ascribed by Mr. Boss to the segregation of a low melting eutectic, whose nature is as yet undetermined*



# Hot Cracks Versus Cold Cracks — to Distinguish Them in Welded Joints

By Gerard H. Boss
Metallurgist
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MOST INVESTIGATORS of welding in the United States apparently assume that there exists only one kind of crack in welded base metal, that is the kind which occurs as a result of high hardenability of the steel. However, there exists another type of cracking whose cause and manner of occurrence have absolutely no relation to the gamma-to-alpha transformation. Since the two kinds of cracks are so fundamentally different in their cause and occurrence, it is important that welding and production engineers be able to distinguish between them so that the proper remedies may be applied.

The first and generally recognized kind of cracks is called "cold cracks" or "hard cracks". The susceptibility of a steel to cold cracks is very closely dependent on its hardenability and rate of cooling after welding. Since these cracks occur below 600° F. the cracked surfaces are always bright. Cold cracks are generally straight lines or smooth curves, which may or may not pass into the weld metal. They may run at any angle to the direction of the

weld. Cold cracks are more apt to occur in arc welding than in gas welding; this is because the oxy-acetylene flame puts more heat into the weldment than the arc does, thereby causing it to cool more slowly.

The second, and poorly understood type, is called "hot cracking" because of the temperature of its occurrence. It is directly related to some form of localized hot shortness. The fact that the cracked surfaces are always covered with a coating of the blue-black magnetic oxide of iron is in accord with the opinion of certain German metallurgists that the cracks occur above 1800° F. Hot cracks are usually crooked, but always run parallel to the weld. They occur in the base metal adjacent to the weld metal, but they never enter it. As can be seen in the photomicrograph these cracks follow the austenitic grain boundaries. Hot cracks are more apt to occur in gas weldments than in arc weldments.

It is believed that the hot shortness which results in hot cracks is caused by the segregation into the austenitic grain boundaries of a low melting point eutectic. Despite an extensive investigation at the Glenn L. Martin Co., the composition and nature of this eutectic was not discovered.

## Weldability—a More Complete Definition

By Dr. Osst I. Temper
Comptroller
High Hardness-Ductility Combine

WE WERE VERY MUCH interested in Martin Seyt's simplified definition of weldability of steel (*Metal Progress* for February, page 298) and his excellent summary of current ideas on the subject. However, weldability, it seems to us, is more complicated, and more difficult to define because of the involved interrelation of welding procedure and plate metal variables. It seems, at first thought, quite logical to restrict the evaluation of weldability to a consideration of the ability of a steel to endure a given welding procedure without setting up conditions which tend to produce failure of either the steel or welded joint during welding or in service. It might also appear desirable to assume that the severity of the welding procedure is purely a function of the severity of the imposed thermal cycle, as implied by the definition ascribed to Hodge and Gibson, and in Dr. Seyt's discussions of the Rensselaer and Lehigh experiments. If the principal criterion of weldability is absence of base metal cracking during the welding operation, a quantitative solution of the problem either by direct determination of cooling rates or by relation of the weld cooling rates to maximum hardness produced in the plate should be possible.

However, there are strong indications that severity of the welding cycle cannot be judged by intensity of thermal cycle alone. Consider first the problem of "hard cracks", usually called "root" or "underbead" cracks (Fig. 2 and 3, page 71). Dr. Seyt states that such cracks do not form if the carbon content of the plate metal is limited to approximately 0.20% and the alloys kept low, or if the weld cooling rate is slowed down by preheating or using a large welding heat. Since these measures all tend to avoid the formation of martensite and to prevent hardness levels greater than approximately 350 Brinell, it might appear that the whole story of hard cracks is one of martensite transformation stresses.

### The Problem of Underbead Cracks

Nevertheless, the above argument does not explain the following facts: Underbead cracks do not form if uncoated ferritic electrodes are used, or if either austenitic or ferritic electrodes having lime or titania base all-mineral type coatings are used, even though the base metal has relatively high carbon and alloy contents and the full martensitic hardness of Brinell 400 to 600 is developed in the heat affected zone. It appears that underbead cracking is definitely a characteristic of weld deposits made with commercial ferritic electrodes having coatings which contain substantial amounts of cellulose or organic materials. It might be argued that this cracking could be explained by differences in the weld metal stresses for deposits made by these various electrodes, but recent experiments by S. A. Herres at Watertown Arsenal and published in a paper entitled "Arc Welding Alloy Steels" in *Transactions*, ●, for 1944, page 535, have shown that underbead cracks are prevented if commercial ferritic electrodes are heated at temperatures sufficiently high to drive off combined moisture and break up cellulosic compounds, and that the cracks reoccur if the electrodes which have once been heated are moistened before welding. This is shown in photographs of welds, kindly loaned by Lt. Herres. (Fig. 4, page 73.)

These and additional experiments (welding with uncoated ferritic electrodes in various atmospheres) may be most reasonably explained at present by assuming that underbead cracks are a flake-like defect associated with hydrogen, absorbed from the welding atmosphere by the molten weld metal; sufficient hydrogen diffuses

## Table II—Weldability of Steel for a Given Welding Procedure (Metal Arc Process)

**Influence of Base Metal Variables in the Production of a Serviceable Structure**

| Principal Base Metal Variables (Mechanical Properties of Base Metal Determined by) | Effect on Base Metal Zone Immediately Adjacent to Weld (Heat Affected Zone): Susceptibility to Cracking During Welding: Underbead Cracks (a) | Effect on Base Metal Zone Immediately Adjacent to Weld (Heat Affected Zone): Susceptibility to Cracking During Welding: Other Thermal Cracks | Effect on Base Metal Zone Immediately Adjacent to Weld (Heat Affected Zone): Properties of Metal in Absence of Cracks | Effect on Weld Deposit and Fusion Zone (Interfused Base and Filler Metals): Susceptibility to Welding Cracks | Effect on Weld Deposit and Fusion Zone (Interfused Base and Filler Metals): Soundness (Exclusive of Cracks) | Effect on Weld Deposit and Fusion Zone (Interfused Base and Filler Metals): Properties of Sound Weld Metal | Effect on Completed Weldment (Magnitude of Locked-Up Stresses) |
|---|---|---|---|---|---|---|---|
| Carbon content | Increase with carbon content | Increase with carbon content | Strength increases, impact resistance decreases with increase in carbon content | General increase with carbon content | Generally, no effect (d) | Strength increases, impact resistance decreases, with carbon pickup | Increase with carbon content |
| Hardenability | Increase with hardenability (b) | Increase with hardenability | Strength increases with hardenability. Impact resistance increases with hardenability until martensitic type microstructure forms, then decreases with hardness of final structure (c) | General increase with hardenability | Certain alloys may contribute to weld metal porosity (d) | Strength increases with alloy pickup from base metal (e) | Increase with hardenability |
| Prior heat treatment | Decrease by a heat treatment, which eliminates hydrogen present from prior processing, or which stabilizes carbides | Increase with yield strength and decrease with increasing ductility as established by prior heat treatment | Heat treatment which stabilizes carbides lowers effective hardenability during welding cycle | Increases with yield strength, decreases with increasing ductility, as established by prior treatment | No effect | No effect | Increase with yield strength, decrease with increasing ductility as established by prior treatment |
| Non-metallic content and distribution | Certain non-metallics (as sulphur) may react with and eliminate hydrogen dissolved in molten weld metal | Cracks may start at nonmetallics, especially if elongated by rolling or segregated at grain boundaries | Inclusions may decrease ductility and impact resistance, especially if elongated by rolling or segregated at grain boundaries; effect is very marked when heat-affected zone has high hardness | Some non-metallics may contribute to weld metal cracking | Certain non-metallics (as sulphur) may contribute to weld metal porosity or slag inclusions (d) | General decrease in strength and impact resistance with increased non-metallic content (d) | No effect |
| Porosity and surface defects | Decrease with increased porosity which permits escape of hydrogen diffused into base metal | Cracks may originate at porosity or surface irregularities | Strength and impact resistance decrease with increase in porosity or surface irregularities, depending largely upon location | No effect known | Surface oxides may contribute to weld metal porosity and slag inclusions | No effect known | Surface irregularities give rise to stress concentrations |

Notes: (a) Underbead cracks are not formed if electrode coating is low in hydrogen compounds.
(b) Effect of certain alloys on solubility and diffusibility of hydrogen may have undetermined influence. Carbide stabilizing alloys may decrease effective hardenability during welding cycle.
(c) In absence of cracks, best combination of strength and impact resistance is obtained when martensitic type microstructure is formed in heat affected zone by first passes and is tempered to a hardness approaching that of the base metal by subsequent weld passes or postheat treatment.
(d) Depends, to a large extent, upon specific gas and fluxing reactions during welding.
(e) Impact resistance increases with alloy pickup from base metal, for usual low carbon ferritic weld metals.

into the base metal to crack the hardened areas during or shortly after the welding cycle. Even though the mechanism be due to hydrogen occlusion rather than martensite transformation stresses, hardness might still be used as a measure of cracking susceptibility, if welds made with the usual type of electrodes were free of cracks when the highest hardness was less than a certain Brinell number. Unfortunately, this is not strictly true.

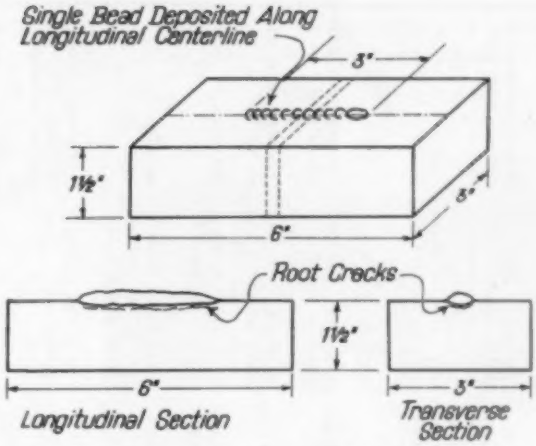



*Fig. 2 — Test Piece for Weld Bead Hardness; Dotted Lines on Perspective Sketch Represent Slice for Crack Inspection*

Underbead cracks have frequently been observed when the hardest part of the heat affected zone was less than 300 Brinell. On the other hand, hardnesses of 500 to 600 have been observed with no indication of cracking. It would appear that the underbead cracking phenomenon is dependent upon a rather critical balance between the amount of hydrogen diffused into the base metal and the ductility of the metal at the time of cracking. Neither of these is truly reflected by hardness measurements, and therefore the best means of determining cracking susceptibility appears to be inspection for cracks on sections of welds made in the same conditions as will be used in fabrication.

Underbead cracks are not the only type of base metal cracks that may develop. It is easily demonstrated that *any* steel may be made to crack by heating and then restraining it so that the steel literally pulls itself apart by contractional stresses or cooling. Any foundryman or heat treater who deals with large or complicated sections has seen many such cracks. Thus, "toe" cracks in a single bead weld deposit, or transverse cracks in a welded joint, are apparently related to the strength of unaffected base metal, to its hot shortness, or a poor distribution of non-metallics in the heat affected zone, as well as to variables in the design and welding procedure.

Ductility of the base metal affected by the heat of welding deserves some discussion, though possibly it is of no great importance in ordinary weldments, provided cracks are prevented during the welding operation. In the first place, I wish to emphasize that martensite of relatively low carbon content (0.30% carbon or less) is by no means inherently brittle. The following properties are not unusual for 0.27% carbon rolled plate material (of sound steel quality, and with sufficient alloy to harden fully in 2-in. section). Figures are for pieces water quenched from 1600° F.

| | |
|---|---|
| Tensile strength | 250,000 |
| Yield strength | 225,000 |
| Reduction of area | 40% |
| V-notched Charpy | 20 to 35 |
| Brinell hardness | 480 |

Strength and hardness of such material decrease by tempering, by heat of subsequent welding passes, or by postheat treatment. At the same time ductility and notched-bar impact energy increase. It is well established that, in the range of 200 to 400 Brinell, a fully hardened and tempered steel has considerably higher resistance to impact, particularly at sub-zero testing temperatures, than steel of equivalent hardness which was initially slowly cooled from the austenitizing temperature.

For weldments designed to resist shock, repeated high load, or low temperature service, and which are preferably made from heat treated steel, it would appear from the above considerations that, in the absence of cracks, the presence of martensite in the heat affected zone is not entirely deleterious. On the other hand, a slowly cooled pearlitic heat affected zone may actually lead to brittle failure through this zone under severe shock loading.

It follows that, for ordinary weldments made from as-rolled or normalized steel and designed

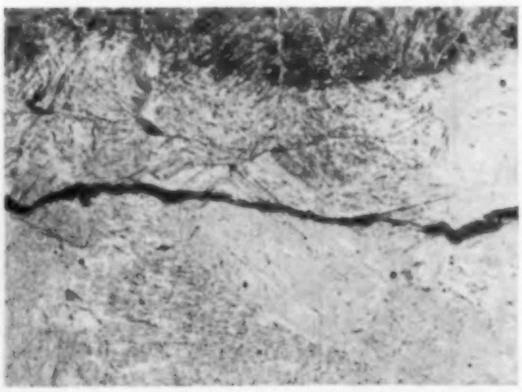


*Fig. 3 — Root Crack Under a Single Weld Bead on 0.40% C Alloy Steel Plate (Longitudinal and Transvere, ×4 and ×100)*

## Table III — Suitability of Welding Procedure (Metal Arc Process) for a Given Base Metal

### Influence of Welding Procedure Variables in the Production of a Serviceable Structure

| Principal Welding Procedure Variables | Effect on Base Metal Zone Immediately Adjacent to Weld (Heat Affected Zone): Susceptibility to Cracking During Welding — Underbead Cracks (a) | Effect on Base Metal Zone Immediately Adjacent to Weld (Heat Affected Zone): Susceptibility to Cracking During Welding — Other Thermal Cracks | Effect on Base Metal Zone Immediately Adjacent to Weld (Heat Affected Zone): Properties of Metal in Absence of Cracks | Effect on Weld Deposit and Fusion Zone (Interfused Base and Filler Metals): Susceptibility to Welding Cracks | Effect on Weld Deposit and Fusion Zone (Interfused Base and Filler Metals): Soundness (Exclusive of Cracks) | Effect on Weld Deposit and Fusion Zone (Interfused Base and Filler Metals): Properties of Sound Weld Metal | Effect on Completed Weldment (Magnitude of Locked-Up Stresses) |
|---|---|---|---|---|---|---|---|
| **Weld Heat Input**<br>Increases with: 1. Current and voltage; 2. Exothermic reactions in arc<br>Decreases with increasing arc travel speed, endothermic reactions, and radiation from arc | Decrease with heat input sufficient to prevent formation of martensitic type microstructure | Increase with heat input, except when it is sufficient for low thermal gradients or low cooling rates | High heat input deepens heat affected zone, increases amount of coarse grained, high temperature structure, with considerable variation of strength and impact resistance of this structure in alloy steels | Decreases with increased heat input | General improvement with higher heat inputs except when followed by slow cooling which may produce porosity | No definitely established relationship between weld heat input and properties of sound weld metal | Locked-up stresses increase with heat input |
| **Weld Cooling Rate**<br>Increases with: 1. Mass of metal adjoining bead; 2. Thermal capacity of surroundings; 3. Conductivity of weld metal<br>Decreases with increasing preheat temperature, interpass temperatures, and insulation of slag deposit | Increase with cooling rate sufficient to form martensitic type microstructure | Increase with cooling rate | Strength increases with cooling rate; impact resistance increases with cooling rate until martensitic type microstructure forms, then decreases with increasing hardness of final structure | Increases with cooling rate | Soundness improved by slower cooling rate, except when preceded by high heat input. See above | Strength increases with cooling rate; impact resistance increases with cooling rate for usual low carbon, ferritic weld metals | Locked-up stresses increase with cooling rate |
| **Composition of Molten Filler Metal** (b) | | | | | | | |
| Carbon content | Carbon has no known effect | Increase with carbon content (d) | Carbon has no effect | Increases with carbon content | Effect of carbon varies (f) | Strength increases; impact value decreases with carbon | Increase with carbon content |
| Alloy content | No effect of alloys known (c) | Increase with alloy content (d) | Alloy content has no effect | Variable, depending on alloy | Effect of alloys varies (f) | Strength and impact generally increase with alloy | Increase with alloy content |
| Non-metallic content | Certain non-metallics may eliminate dissolved hydrogen | Non-metallic content has no effect known | Non-metallic content has no effect | Certain non-metallics may possibly contribute | Certain non-metallics increase porosity | General decrease with non-metallic content | No effect |
| Gas content | Increase with amount of hydrogen in solution | No effect definitely established | Hydrogen causes general embrittlement. Effect decreases on aging | Hydrogen probably contributes | Effect varies (f) | Hydrogen embrittles; effect decreases on aging | No effect |
| **Restraint on Weld Joint**<br>Increases with the rigidity of the structure; decreases by variation in sequence of joints welded, or deposition in joint | Growth of cracks, once formed, facilitated by increase of restraint | Increase with degree of restraint | Effect not definitely established | Increases with degree of restraint | No effect | Effect not definitely established | Locked-up stresses increase with degree of restraint |
| **Reheating After Initial Deposition** | | | | | | | |
| By subsequent weld deposits | Decrease when interpass temperature prevents martensitic microstructure | Decrease with sequences producing low thermal gradients or cooling rates | Strength decreases; impact resistance increases with increased interpass temperature (e) | Decreases with sequences producing low thermal gradients or cooling rates | No effect | Strength decreases (e) | Decrease with sequences producing low thermal gradients or cooling rates |
| By postheat treatment (subcritical stress relief anneal) | Does not prevent formation but limits their growth | | Strength decreases; impact resistance increased with tempering time and temperature (e) | Does not prevent, but limits growth | No effect | Strength decreases (e) | Decrease with higher temperature, time at temperature, and slower cooling |

NOTES: (a) Underbead cracks are not formed if electrode coating is low in hydrogen compounds.

(b) Controlled by core wire and coating compositions and atmospheric conditions.

(c) Effect of certain alloys on solubility and diffusibility of hydrogen have undetermined influence.

(d) Carbon and alloy contents of weld metal are not serious factors in thermal crack formation in heat-affected zone of low carbon, low alloy base metals.

(e) Impact resistance increases with increased interpass temperature, or with increases in annealing time and temperature, except for precipitation hardening alloys in which case the opposite effect may be obtained; deleterious effects may be obtained if austenitic type weld or base metals are reheated.

(f) Effects of carbon, alloy content, and gas content which may tend to produce unsound weld metal are influenced by specific gas and fluxing reactions during welding; controlled to a large extent by electrode coating composition.

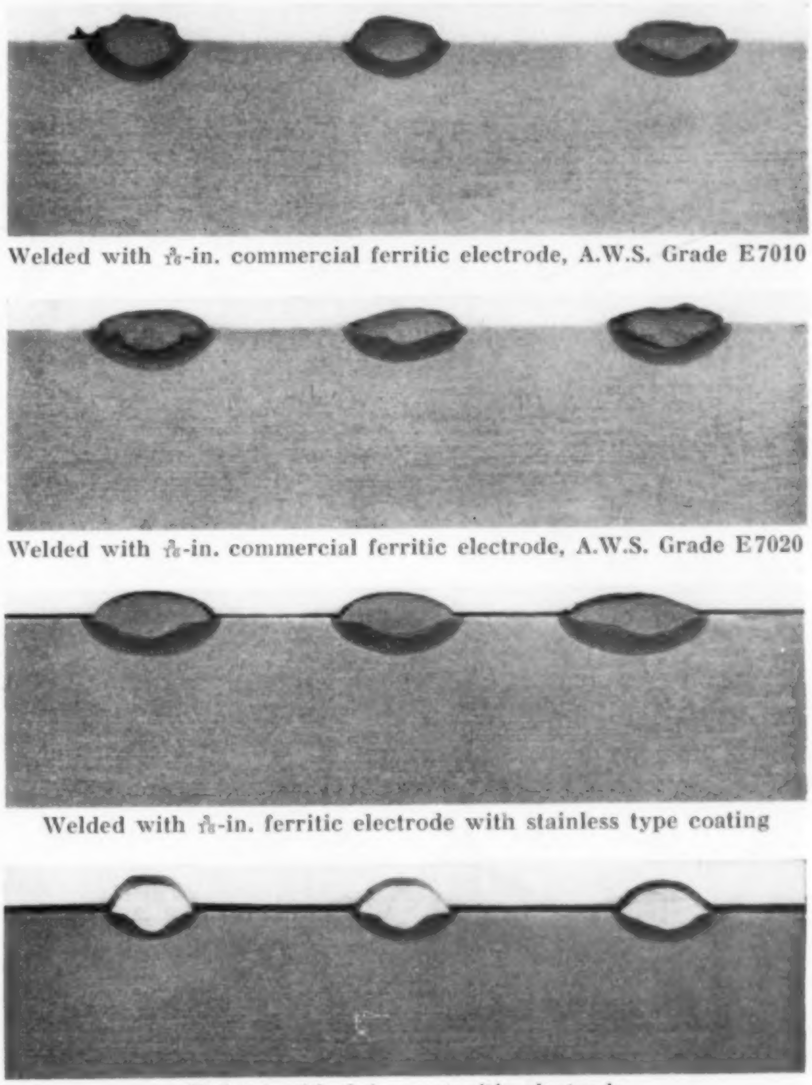
for service well within the elastic limit of the structure, a requirement for a certain ductility in a test weld is valueless except as a means of disclosing base metal cracks. In the absence of such cracks, plate metal defects, or severe notches, failure of these weldments, in my experience, always originates in the weaker weld or unaffected base metal rather than in the heat affected zone.

A *complete* weldability definition probably should take into account all influences of base metal variables on production of a serviceable welded structure. In addition to the conditions in the heat affected zone which have already been discussed, the influence of the base metal variables on soundness, strength and cracking susceptibility of weld metal, and on the magnitude of undesirable locked-up stresses in the structure may be important. (For a discussion of the importance of locked-up stresses in welded structures, see J. Tutin, "Locked-Up Stresses", in *Steel* for February 17, 1944, page 136.)

Table II on page 70 illustrates the influence of the principal base metal variables on the conditions which may cause a steel to be classed as unweldable, while Table III, opposite, illustrates the influence of the principal welding procedure variables on these same conditions. Present knowledge does not permit adequate treatment of all these variables, but I believe that such tables are useful as a method of separating out the factors and studying them individually so that, in time, it may be possible to revise and complete them.

*Fig. 4 — Macro-Etched Transverse Sections Through Single Weld Beads Deposited on Normalized 6150 Steel*

Deposited With Untreated Electrode — Deposited With Dried Electrode — Deposited With Electrode First Dried, Then Wet



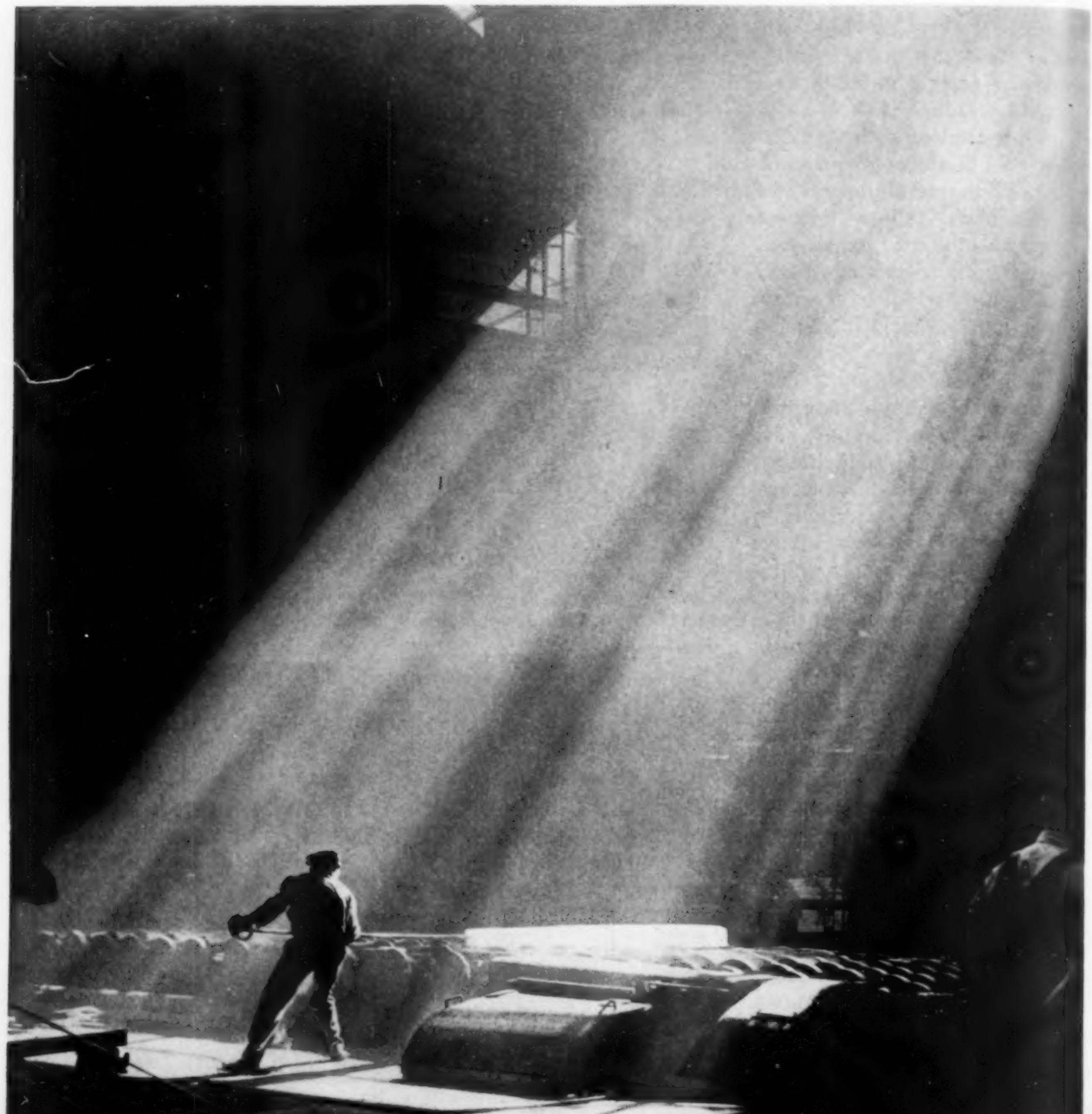
Welded with 3/16-in. commercial ferritic electrode, A.W.S. Grade E7010

Welded with 3/16-in. commercial ferritic electrode, A.W.S. Grade E7020

Welded with 3/16-in. ferritic electrode with stainless type coating

Welded with 3/16-in. austenitic electrode

The problem of the welding engineer is to determine the most economical and practical compromise between weldability of base metal and suitability of welding procedure which will satisfy the requirements of a specified structural design. To do this he must devise inspection methods and control tests which will assure him that the base metal finally selected has sufficient weldability under the exact conditions of welding which will be used in fabrication. In this connection the usual methods of relating weldability either to maximum hardness in the heat affected zone or to ductility in a bend test (unless used as a preliminary, or actually correlated with service performance by a background of experience for a given welding application and base metal analysis) are not as illuminating as a system of crack inspection by macroetching or magnafluxing sections of typical or duplicate joints of the particular weldment. In some instances weldability may be evaluated by testing to destruction actual or simulated weldments or sections of weldments. For many applications, final and complete evaluation must await an analysis of service experience.



*Plates, Plates, More Plates!*

*Approach tables to 140-in. mill. This — and others like it — sent 13 million tons of steel plate to our shipyards in 1943*

# Steel—

# Yesterday, Today and Tomorrow

By R. E. Zimmerman,
Vice President,
United States Steel Corp. of Delaware,
Pittsburgh, Pa.

*In this address, delivered in May before the Annual Meeting of the American Steel Warehouse Asso. in Chicago, is contained a conservative appraisal of the future uses of steel products as affected by the research and technical developments of the recent war years. Purchase of steels by properties in fabrication and use, rather than by chemical analysis, is listed as a future trend. General improvement in uniformity, surface and gage is predicted through better steel making processes; wider use of low alloy and "intensified" (boron) steels is certain; better heat treating and welding techniques will make better products for civilian customers. Dr. Zimmerman also believes much light gage steel will go into small buildings and residences.*

MOST OF YOU KNOW, statistically, what is happening to the steel industry these days. You know, for example, that in 1939 when Germany invaded Poland, the annual ingot capacity in this country was approximately 82,000,000 tons, and that there was plenty of steel for civilian uses. The ingot capacity is now in excess of 94,000,000 tons, and civilian consumption is highly restricted. In 1939, in the days of plenty, the production of ingots was 52,500,000 tons; last year it was 88,800,000. Against that let us set the ten year average peacetime figure, 37,400,000 tons, and the comparison is impressive.

The purpose of citing these figures is not to benumb you with statistics but rather to suggest something of the atmosphere in which the steel fraternity will be working when the war ends. Certainly there will be an abundance of steel products for unrestricted sale, and unless the law of supply and demand is repealed, plenty of competition.

Steel has not been alone in the enormous expansion of productive capacity, nor in the matter of persistent research and development. Vast quantities of aluminum, magnesium, metal powders, castings, plastics and plywood will be seeking peacetime markets as never before. They will be supported by an impressive fund of knowledge and determination, not hesitant about reaching into fields heretofore served mainly by steel products, wherever and whenever there seems to be a chance that substitutes can meet the requirements, technically and economically. No doubt there will be overlapping areas in which competition will be quite pronounced.

The history of most products has been that they have found logical and proper applications in which to serve the needs of mankind. With such diversified requirements as our present complex civilization has to fill, we welcome each new substance in turn, believing that it has something to contribute to progress. It usually has. We observe with interest, however, that the metal which held sway in the remote years of the Bronze Age has not yet passed into oblivion, and that there are more candles made and sold now than in the days when man depended mainly upon them to light the darkness.

From time to time many fancy tales, based upon too little data, are to be read about this or that material and what it will do to render most of the others obsolete. Steel itself is sometimes an offender in this regard. Unfortunately, all such statements are not submitted promptly to widespread technical and economic analysis. Calm appraisals might readily show wherein certain claims are exaggerated. Competitive mate-

rials, too, have their shortcomings and handicaps as well as their good properties. Some of them, such as plywood and the plastics, are organic, and certainly cannot serve at high temperatures. On account of their low strength and high cost, the plastics can hardly be considered formidable contenders in structural applications. Some of the metals are none too resistant to the effects of heat, even below the red range. Again, while the light metals admittedly are light, they sag much more than steel under load, because of their low modulus of elasticity. Hence in the design of structures, full advantage of their relatively low density cannot always be realized.

Workability, strength, weldability, resistance to wear, relative cost, and many other factors raise questions which must be answered in individual cases before a material can be approved for widespread purposes. So, while inter-product competition lies ahead and is not to be dismissed as inconsequential, steel is by nature well equipped to make a case for itself, if its sponsors do not become afflicted with an unwarranted feeling of timidity.

## Performance Rather Than Analysis

While laying before you these considerations, likely to be found in the future, we should like to mention a trend which may readily increase in emphasis. It is the tendency to buy and sell properties and performance rather than just so much carbon, phosphorus, sulphur, and metallic alloying elements in steel. A customer usually knows what services he would like to have a steel perform; he may or may not know how to translate his desires into terms of chemical composition. He wishes a grade of steel to do the job at hand. The controlling requirement may be a specified depth or range of hardenability, or ready weldability with moderate accompanying strength, or particularly good machinability "with as much toughness as possible". In any one of these cases there might be several compositions which would do equally well; one might be readily available and the other subject to extended delivery. By arranging purchases on the basis of requirements to be met in service rather than upon the arbitrary specification of one chemical composition, the customer might often do himself an extraordinarily good turn, at no inconvenience to his supplier.

The remaining discussion may be devoted, advantageously, to considering the future effect of wartime research and development.

In the first place, we should recall that when the national emergency came upon us, research was already organized, entrenched, and functioning in the steel industry. The development of basic material for armament and munitions did not have to "start from scratch". A vast fund of metallurgical and engineering knowledge had been accumulated, and experience in producing steel to the exacting requirements of the great and diversified manufacturing industries of this country was extensive. Truly enough, in facing the mounting needs of the armed services, emphasis had to be shifted quickly to accommodate the specific demands for grades of steel with special combinations of properties, but the high level of existent knowledge served as an excellent starting point. The general know-how in research was on hand, awaiting application.

As is usual, the pace of research and development was greatly accelerated by the advent of war. Normally-moving projects became urgent; different parts of the field were explored; the tempo of all necessary investigations was quickened; speed became a more important ingredient in all programs of research. As a result of the acceleration you will find, at the cessation of hostilities, a large dividend of additional knowledge added to the yield of appropriate normal developments for the period in question. That is sort of a promise; I shall try to indicate what it comprehends.

Among the matters which appear as certainties, mention may be made first and appropriately of the general improvement of quality resulting from advancements in the steel making processes. Continued study of the physical chemistry of steel making, contributing to better regulation of metallurgical reactions, slag composition, temperature, and degree of deoxidation, has led to greater refinement in practice and better control of product. Now, unfortunately for purposes of exposition, there is nothing glamorous about singing the praises of improved carbon steel plates, shapes, bars, and similar products, or in extolling the virtues of the improved processes and equipment back of them. The mere mention of one decidedly new but relatively unimportant steel product would outweigh, in popular interest, a full account of the immense amount of effective engineering and metallurgical work expended in enhancing the useful characteristics of the more common products. Yet there are few factors which surpass in importance the one just proclaimed.

A second matter, which likewise has most favorable implications, stems from the large wartime expansion of the steel industry. The great increase in capacity during the past several years has brought with it some of the finest and most

improved equipment — mechanical, thermal, and electrical — ever devised. You will readily appreciate what this can mean with respect to maintenance of contour and gage, uniformity of quality, and surface finish.

The third item for mention here promises something in the way of products, but at the moment carries a few shearing fins. Wartime research has greatly intensified the study of the role of the alloying elements in steel, making for their more rational use in setting up desired combinations of properties. The trend away from an excessive number of grades of alloy steel was well under way before the war, and interested technical groups were working upon a simplification of the unwieldy list of specifications. In the emergency, recourse had to be taken to progressively smaller lists of permissible grades, until finally the matter became critical, and the number was reduced, by official directive, to a minimum. A special aspect was the development of the National Emergency steels to meet the crisis caused by the too rapid exhaustion of our available supply of such metals as chromium, vanadium, nickel, and molybdenum. The NE steels, so called, were designed to make the most effective use of the strategic materials on hand, utilizing the alloy content of carefully segregated scrap insofar as possible. Metallurgically they relied in most instances upon the cumulative effect of relatively smaller amounts of multiple alloying elements, rather than upon that of larger percentages of one or two.

The principal members of this series of new, particularly the triple alloy (chromium-nickel-molybdenum) types, have been performing valiant service. They have helped solve a difficult situation, have saved large quantities of alloying elements, and may be important factors in the simplified list of standard grades available after the war. Economics and metallurgy will chase each other around the stump before a clear decision on this point is reached in times of normal commercial enterprise. Moreover the size and condition of the alloy steel scrap pile will have an influence upon the future of the National Emergency Steels when the word "Emergency" is dropped from the name.

Another interesting development, the fourth in line for review, is that of the so-called "intensified steels". They are designated as such because there is added to the molten steel, after it has been deoxidized, one or another of a group of rather unusual metallurgical agents, which seem to intensify certain effects of the more common alloying elements. "Certain effects" means particularly, or almost exclusively, hardenability. There is quite a variety of these addition agents, but they all contain boron in some form, hence in some quarters the treated products are referred to as "boron steels". The intensifying effect is quite pronounced, it does afford a means of conserving metallic alloying elements, and the steels are being applied in substantial tonnages to war requirements which have peacetime equivalents. It should be stated that the work on this development was started some years before 1940, but that it received its principal impetus and came into fruition more recently. Further research work is in progress, on an extensive scale, and metallurgists look for a considerable increase in the use of the intensified steels, not only during the remainder of the emergency, but also in the ensuing years.

## Advances in Heat Treatment

Now as a fifth item, but not fifth in order of importance, something must be said of the immense amount of work which has been done on the heat treatment of steel during this period of inordinate activity. From armor plate to bayonets, or from helmets to cartridge cases, as you choose, the field has been explored with painstaking care by producers and fabricators of steel. The best of existent technological data has been fortified by additional intensive studies. Precise procedures and properly regulated cycles, based upon detailed metallurgical investigations of the steel to be treated, have been devised and specified. They have been implemented with adequate equipment, controlled by excellent instruments, and followed by heat treaters enthusiastically because of the superior results achieved. Excessive cracking, distortion, and lack of uniformity had to be overcome to meet production schedules — and were overcome. This advancement in the science and practice of heat treatment, fostered as a necessary part of the war effort, will be a boon to the steel business in the succeeding era.

Matching in importance the developments in heat treating, I mention as item number six the forward sweep of welding as a tool of fabrication. Without the modern techniques and practices of welding, the amazing performance of American industry in meeting the requirements of the armed services, with admirable speed, would have been impossible. Grades of steel which a few years ago were not considered commercially weldable are now welded satisfactorily, as a result of concerted study and effort. Because of the widespread use of welding in its various forms for so many purposes, "weldability" as a

characteristic of any steel offered for sale is becoming a primary consideration. Good weldability in any grade goes back through the various processes of production and is one of the objectives of the producer. Purchases will be made on an increasing scale with weldability as a requirement, and in due time may be mentioning air-hardening, residual stresses, checking, and the effect of thickness. Thus you will find that the present emergency has pushed the clock ahead.

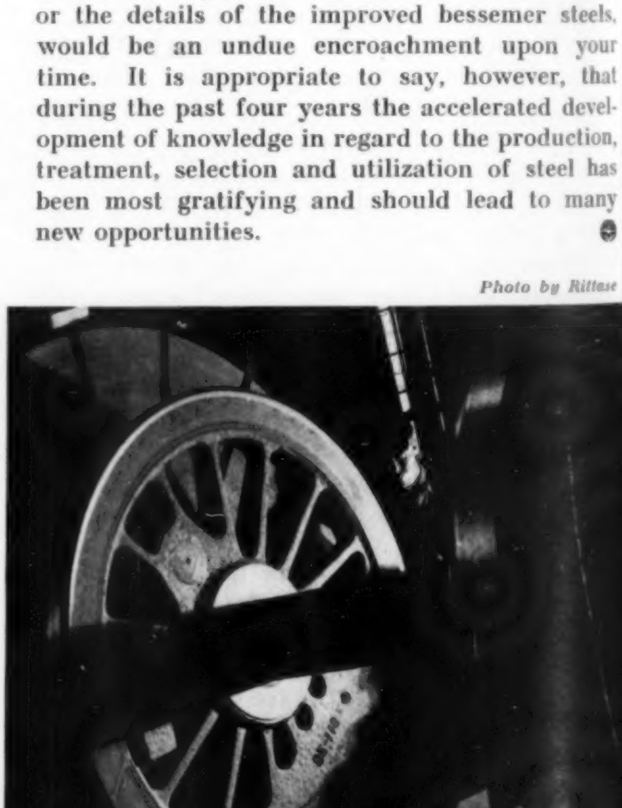
In the case of the next or seventh item, however, the clock stopped. It stopped because of the necessity of devoting attention, in unreserved measure, to wartime steels and to the conservation of alloying elements. Reference is to the low alloy steels of high strength and high resistance to corrosion. They were developed and well on their way in 1941, doing service mainly in mobile equipment such as railroad cars, trucks, power shovels and even ships. The principal merit of these steels was that they lent themselves to designs and constructions by which a substantial percentage of dead weight was eliminated, by virtue of the coincident features — marked corrosion resistance and enhanced tensile properties. The war effort merely postponed but did not eradicate this development. In many fields the economies to be realized from reductions in weight are too important to remain dormant indefinitely; hence the idea is growing into a potentially widespread post-war demand.

Continued research throughout recent years has contributed much to the development of steel products electrolytically coated with tin, zinc, and other metals. They will be available for commercial uses after the war. In quite a different category we find some of the highly alloyed steels, further developed for particular needs of the armed services, which will likely be applied to special purposes in the future. One such is the material now used for gas turbine blading, often called "supercharger steel", which is well adapted to operate at the high temperatures encountered in the exhaust systems of airplanes. Then there are the well known members of the stainless steel family, improved and better than ever, which will be ready to shift from the service canteen or mess hall to the home and hotel and restaurant, when the signal is given. Essential processing industries have been demonstrating the merits of the chromium-nickel-molybdenum stainless grades for many purposes, and have enjoyed the versatile corrosion resistance of the more complex alloy.

All of you know that the armed forces have extended the use of steel in huts, task force buildings and many small structures. This experience has been quite in harmony with the idea of incorporating steel, much more extensively, into the construction of residences and commercial buildings. One bit of research which has an important bearing upon this wider use of steel is the systematic study, now yielding practical results, of the engineering characteristics of cold formed, light weight structural members for just such purposes. Before long the steel industry will offer the newly acquired data to designers so that they may take full advantage of it in planning their structures. The broad aspect of this line of engineering research is that it will aid in the rational utilization of steel — and thus benefit all parties concerned.

Now all that has been said in this attempt to tell you something of what has been happening to the technology of steel during the war is indicative rather than comprehensive. We are not in position to close with the familiar words of one of the radio news commentators, to wit, "and up to the minute that is all of the news". To go into such matters as the influence of compressive stress on the fatigue endurance of steel, or the latest procedure for crackless hardening, or the details of the improved bessemer steels, would be an undue encroachment upon your time. It is appropriate to say, however, that during the past four years the accelerated development of knowledge in regard to the production, treatment, selection and utilization of steel has been most gratifying and should lead to many new opportunities.

*Photo by Rittase*



# "Available" Beryllium in Copper

By H. G. Williams
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*Beryllium-copper having the required analysis may fail to develop expected properties. Beryllium present but not "available" for hardening is often responsible for this trouble, as well as for certain difficulties encountered in fabrication*

BERYLLIUM-COPPER, as is well known, is hardened by the precipitation of beryllium from its solid solution in copper (the alpha phase). The precipitate is known as the gamma phase. Obviously, therefore, precipitation hardening can only be brought about by the beryllium that is present in the alpha phase after the so-called solution treatment. Beryllium in any other form in the alloy than the solid solution is therefore not "available" for hardening.

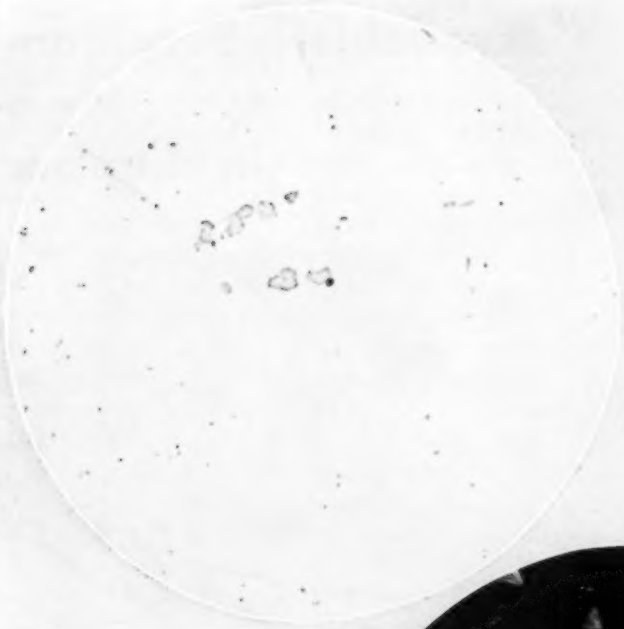
The term "available" beryllium in the title of this brief article means that beryllium which is in solution in the alpha phase. This available beryllium is what the spring manufacturer has to work with and determines the final spring properties.

Present specifications for beryllium copper (American Society for Testing Materials, B-120) call for the following analysis:

| | |
|---|---|
| Beryllium | 1.90 to 2.20% |
| Additive elements to control grain size (nickel or cobalt) | 0.50% max. |
| Other impurities | 0.50% max. |
| Copper | balance |

Few suppliers furnish metal with over 2.0% beryllium due to the difficulties of casting and rolling higher alloys. So here is the first limitation to the maximum possible amount of available beryllium. Next, the additive elements such as nickel or cobalt tend to combine with beryllium to form beryllites, as shown in Fig. 1, which lock up a certain amount of the element and so have the effect of reducing the amount of beryllium that remains for solution in the alpha phase; these added elements therefore tend to reduce the amount of available beryllium. Finally, the specification allows 0.5% other impurities which may include silicon, iron, aluminum, tin, chromium or phosphorus. Some of these impurities may form compounds with beryllium as well as affect the solubility of beryllium in copper, further reducing the available beryllium for hardening. All of these factors are to some degree predictable if a complete chemical analysis is obtained for the material, and reliance is not placed upon a beryllium content alone.

However, the factors having the largest effect on the available beryllium are due to mill and foundry practice and are not revealed by chemical analysis. Theoretically about 2% beryllium may be dissolved in copper and retained there by proper casting and mill procedure. If, however, large castings are made and slowly cooled, considerable amount of beta phase will form. This second phase contains from 4 to 10% beryllium, and even a small amount of it removes much beryllium from the alpha solution. This beta phase, when poorly distributed or found in clumps or stringers (shown in cross section in Fig. 3) may have several undesirable character-



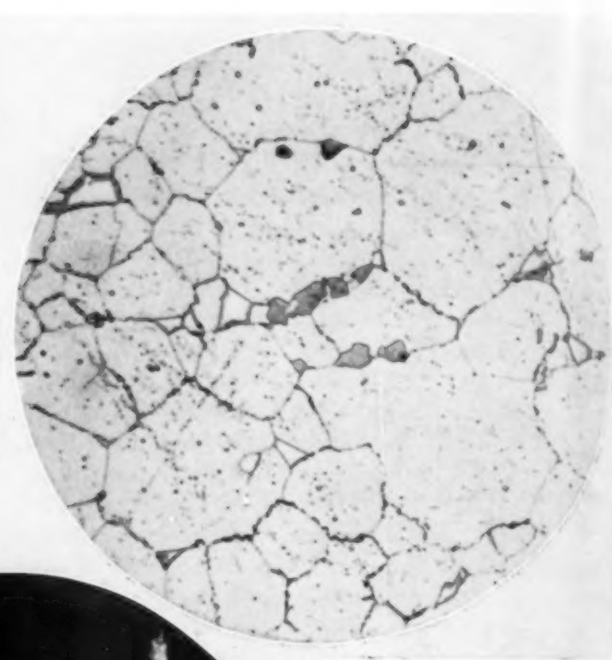


*Fig. 1 (Left, Above) — Specimen of Beryllium-Copper, Unetched, at 500 Diameters, Showing Beryllite Particles*

*Fig. 2 (Right, Above) — Same Specimen as Fig. 1, Etched to Bring Out Both Beryllite and Beta Phase, the Latter Being Lighter in Color With Gray Borders. Both constituents deplete alpha phase of beryllium. Cross section of specimen, not heat treated. (Micrographs courtesy of L. MacNaughton, Materials Laboratory, Sperry Gyroscope Co.)*

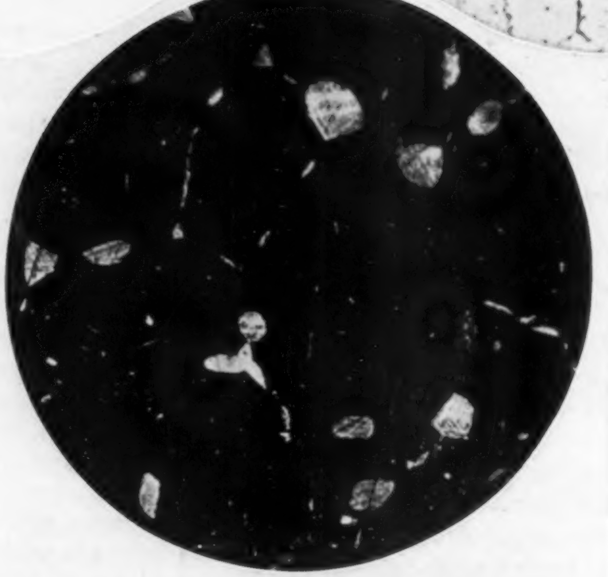


*Fig. 3 (Center) — Normal Condition of Beta Phase Distribution in Average Material. Beryllium content of beta phase reduces the amount of beryllium available for hardening. Cross section, heat treated and etched; 250 diameters. (Courtesy Pease Laboratories)*

*Fig. 4 (Below) — Complex Structure at Grain Boundaries Has High Beryllium Concentration, and Robs Alpha Phase of Its Hardening Constituent. Cross section, heat treated and etched; 500 diameters. (Courtesy L. B. Barker, Works Laboratory, General Electric Co.)*

istics, but the only effect of the beta phase that we are interested in at the moment is that it lowers the available beryllium in the alpha phase. Since it does so in a varying degree, the available beryllium becomes an unpredictable factor unless the microstructure is examined. With excessive beta, an alloy containing 2% beryllium by analysis may have no more than 1.5% in solution in the alpha phase.

Another major source of loss in beryllium available for hardening is a condition variously described as "grain boundary precipitate" or "grain boundary gamma" as shown in Fig. 4. This formation is tied up with faulty mill practice, although the cause or composition of this boundary phase is not fully understood. Its effect is to form clumps or masses of a phase along the grain boundaries that have many undesirable consequences, among them excess distortion of the piece when heat treated. But this phase does contain a high per cent of beryllium which reduces the amount of beryllium in solution and available for hardening.

Beryllium content has an important effect on the *rate* at which precipitation hardening takes place. Masing and Dahl, in work reported in 1928 and described in Rimbach's translation of the book "Beryllium and Its Alloys", found that an alloy containing 2.39% beryllium heat treated at 660° F. reached peak hardness in 1 hr., while an alloy with 1.82% required 9 hr. at the same temperature. Our own experience has shown similar effects at both higher and lower temperatures; also that variations in beryllium available for hardening have the same effect on hardening rate as variations in beryllium content.

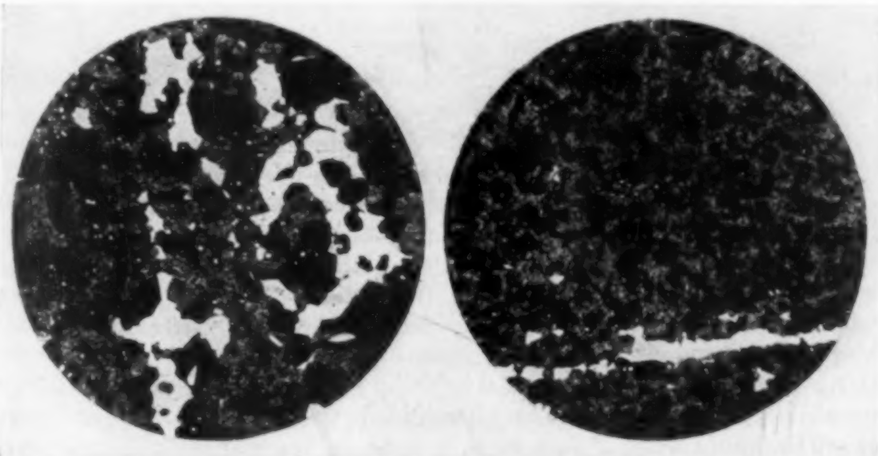


*Fig. 5 — Cross Section (at Left), and Longitudinal View of Same Specimen Showing Excessive Beta Phase and Grain Boundary Constituent. Although chemical analysis was over 2% beryllium, hardening response was no higher than for a 1.5% alloy. Magnification: 250 diameters. (Instrument Specialties Laboratory)*

Beryllium distribution affects the performance of beryllium-copper in three ways:

1. Physical properties obtainable by heat treatment are directly affected by the amount of available beryllium rather than by total beryllium content.

2. Beta phase and the grain boundary constituent, in addition to reducing available beryllium, have detrimental effects on quality and performance of the alloy.

3. Amount of beryllium available for hardening has a large effect on the time required to reach maximum hardness.

No direct method of measuring the amount of available alloy has yet been developed. The only practical solution to this problem is to determine the rate of response for each lot of material, and follow this test with examination of the microstructure on any lot having a low or slow hardening response. One or both the conditions shown in Fig. 5 may be responsible. Preliminary examination, lot by lot, or even of each coil of wire or rod is not too difficult nor expensive in the manufacture of high quality precision springs. Experience indicates, approximately, the optimum temperature for solution and precipitation, as it varies with size of part and specified service requirements. Then a series of small samples from each test lot are heat treated, the only variable being time at temperature for precipitation, and a hardness-time curve drawn from the results. Exact treatments can then be planned for those coils whose curves indicate an equivalent response.

When the material reaches the form of finished wire or strip, no corrective measure short of a full anneal can be helpful, and at this stage even an annealing operation will usually have but small effect. If each lot is tested for hardening response, it can then be heat treated at the one time and temperature to give best performance. No standardized heat treatment can be expected to develop desired properties unless the beryllium available for hardening is specified and controlled in mill fabrication.

# Strong, Fine Wire;

# Non-Magnetic

## Manufacture of Fine Wire of Hadfield's Manganese Steel

**By Herbert H. Uhlig**
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A CRITICAL SHORTAGE of chromium and nickel has stimulated the use of manganese compositions wherever applications permit. Austenitic Hadfield manganese steel, containing 10 to 14% manganese and 1.0 to 1.5% carbon, is a logical substitute for many uses of austenitic 18-8 chromium-nickel steel. The manganese alloy, although not corrosion resistant, possesses mechanical properties equal to 18-8 and is non-magnetic as quenched and after cold work. Stainless 18-8, on the other hand, becomes magnetic upon cold working. Chromium-nickel alloys of this general composition must contain as much as 12% nickel[1] in order to remain practically non-magnetic to the same degree as the Hadfield manganese steels.

However, wires of Hadfield manganese steel, high in carbon, are difficult to prepare because of the severe work hardening properties of the alloy. Brinell hardness may rapidly increase from 180 for the quenched alloy to 450 or even 550 after cold work. The low carbon 12 to 14% manganese-iron alloy, on the other hand, does not work harden to nearly the same degree, and consequently is easily drawn into wires of small diameter. These cold drawn wires are largely ferritic and appreciably magnetic. To obtain the desirable properties of the austenitic alloy, it is possible to carburize the low carbon wires, particularly if the diameter is small, in a manner which is described below. The austenitic wire obtained by carburization must be further cold drawn to size in order to achieve highest strength. This is accomplished without difficulty in a small size wire. The final wire possesses a tensile strength of the order of 300,000 psi. for 10-mil (0.010-in.) diameter, and is practically non-magnetic.

Low carbon manganese-iron wires for this investigation were drawn from swaged ingots cast from a heat of electrolytic iron and electrolytic manganese. The analysis showed 14.4% manganese and 0.03% carbon.

Wires of this composition, 20 mils in diameter, were carburized in a mixture of hydrogen and xylene. This was done by suspending the wire in a horizontal pyrex tube and heating to 1000° C. (1830° F.) by passing a constant electric current (10.1 amp.). Temperatures were determined by an optical pyrometer. Interrupting the current through the fine wire, surrounded in the cold hydrogen-xylene atmosphere, was the same as a rapid quench. Carburization equivalent to 1% carbon absorption required only 1 min. at 1000° C., but the carbon so absorbed resided largely in a surface layer of the wire as the photomicrograph of Fig. 1 proved.

To diffuse this carbon to the center, the wire was heated an additional 3 min. at 1000° C. in a dry hydrogen atmosphere. Hydrogen purified by copper at 400° C. (750° F.), and dried by passing over $P_2O_5$ and through a liquid air trap, was found to have only a slight decarburizing action. This was checked by careful weighings of wires before and after homogenization, and is the expected behavior of dry hydrogen from previous

[1] J. B. Austin and D. S. Miller, *Transactions* ⊕, Vol. 28, 1940, p. 743.

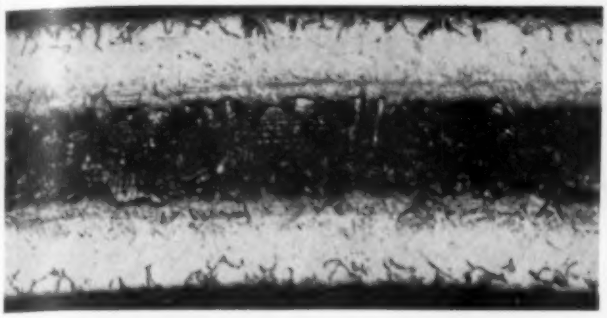

*Fig. 1 — Alloy Made of Electrolytic Iron and Manganese Carburized in Gas, 1 Min. at 1000° C. Magnified 100 dia. Fig. 2 — Homogenization for 3 Min. at 1000° C. Produces Uniform Austenite (0.97% carbon.) Micros by Constance Brodie*

investigations of the decarburization of iron.[2] Micros of wires so homogenized showed that the alloy was completely austenitic (Fig. 2).

Mechanical properties of wires carburized in this manner are given in the table. An 18-8 composition (19% Cr, 9% Ni, 0.8% Cb, 0.07% C) is included for comparison. Magnetic attraction designated "nil" was for wires which, when suspended, were not attracted to a "C" alnico magnet measuring 2¾ in. at the largest diameter. "Slight" indicated some attraction, but not enough to support the weight of a piece about 1 in. long. "Magnetic" was applied to wires which in 1 in. or longer lengths could be picked up.

The tensile strengths of quenched 20-mil wires were considerably increased by cold drawing to 10 mils, but decrease in elongation accompanied the strengthening. The 18-8 alloy became magnetic by this process, independent of previous treatment. The Hadfield alloy gained only slight magnetism (Wire A in the table), and even this was avoided when the 20-mil wire was pickled before the cold drawing operation (Wire B).

The effect of pickling to insure a non-magnetic cold drawn wire is explained as follows: It is probably connected with some loss of carbon and evaporation of manganese that takes place during the heat treatment. It was possible to detect manganese chemically in a slight film which condensed on the pyrex tube. The loss occurs at the wire surface leaving a superficial layer of alloy too low in manganese or carbon or both to remain as austenite when plastically deformed. This slightly magnetic layer is removed by pickling in dilute sulphuric acid.

[2] J. V. Emmons, *Transactions*, Am. Inst. Mining & Met. Engrs., Vol. 50, 1915, p. 405. C. R. Austin, *Transactions*, Vol. 22, 1934, p. 31.

The small time factor necessary for carburizing and homogenizing suggests that both of these operations can be combined in a continuous process. Wires heated by an electric current can move directly from the hydrocarbon atmosphere into pure hydrogen, for homogenization. To increase mechanical strength it is feasible to pass the wire finally through a cold die before the wire is wound on a reel.

**Summary** — Non-magnetic wires of difficult-to-draw Hadfield manganese steel can be produced by carburizing the easier drawn, low carbon manganese-iron alloy. Gas-phase carburization, followed by homogenization at 1000° C., required only 4 min. for 20-mil wire. The resulting wire contained about 1% carbon and was completely austenitic. A 75% reduction of area yielded non-magnetic wire, having a tensile strength of the order of 300,000 psi., which can be substituted for critical 18-8.

**Properties of Carburized 14.4% Manganese-Iron Wires Compared With 18-8**

| Wire | Carbon | Tensile Strength Psi. x $10^{-3}$ | | Elongation | | Magnetic Attraction | | Treatment |
|---|---|---|---|---|---|---|---|---|
| | | 10-mil | 20-mil | 10-mil | 20-mil | 10-mil | 20-mil | |
| A | 0.97% | 144 | 133 | 70% | 51% | nil | nil | Quenched from 1000° C. |
| | | 284 | | 5 | | slight | | Same, cold drawn 20→10 mils |
| B | 1.05 | 141 | 129 | 66 | 50 | nil | nil | Quenched from 1000° C. |
| | | 324 | | approx. 0 | | nil | | Same, pickled, cold drawn |
| 18-8 | 0.07 | 101 | | 25 | | nil | | Quenched from 1000° C. |
| | | 211 | | 3 | | magnetic | | Same, cold drawn |

# Defects in Magnesium Castings From Poor Heat Treatment

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*An article in the May issue listed the causes and cures of common defects in magnesium sand castings arising from aberrations in molding, melting, pouring and solidification. About five additional troubles may arise in a good casting if the subsequent heat treatment is improper, and these will now be discussed briefly.*

DEFECTS in magnesium castings, due primarily to incorrect heat treatment, may be briefly listed in the following tabulation, repeated from the first instalment of this article:

| | |
|---|---|
| Lack of solution | Too short time of treatment or too low temperature. |
| Eutectic melting | Too high temperature of treatment; too rapid rise to heat treating temperature. |
| High temperature deterioration | Water in the furnace; lack of protective atmosphere. |
| Warpage | Internal tensions; improper loading or poor support in furnace during heat treatment. |
| Grain growth | Cold straightening, or other causes of excessive residual stresses occurring prior to heat. |

These matters will now be examined in some detail, and illustrations given.

**Lack of Solution** — Two types of incomplete solution can be distinguished; the one caused by too short a time and the other caused by too low a temperature of heat treatment. The first is shown, microscopically, in Fig. 17.* Solution has taken place but is not completed on account of the short time, and some of the soluble constituent is left undissolved, forming a complete network at the grain boundaries.

The second type is shown in Fig. 18 — very little constituent is dissolved and a pronounced coring is revealed by etching. Re-precipitated phases can also be seen at grain boundaries.

In both cases the mechanical properties of the casting will be low, lower in the second case because the alloy had been annealed, rather than solution treated. Low mechanical properties will be the first indication of improper heat treatment. The microscope will then detect the cause. Once

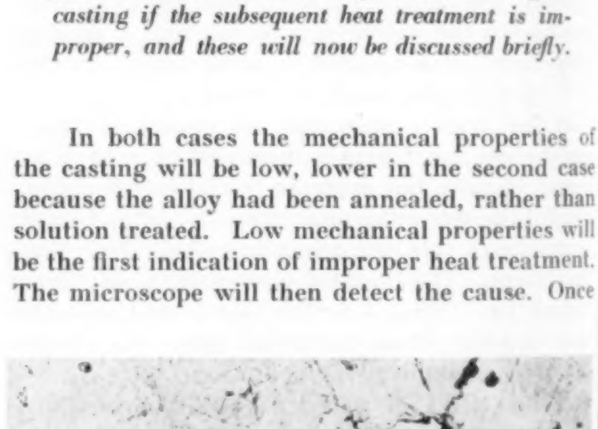


*Fig. 17 — Incomplete Solution; Too Short a Time of Heat Treatment. Microscope shows thin network of AlMgZn constituent at the grain boundaries, typical of this defect. Magnified 250 diameters; etched with 1% nital*

*Illustrations in the two articles are numbered serially.

the cause is found the correction is obvious. When lack of solution is detected, castings can be heat treated again. Amount of constituent not dissolved, importance of the casting, heat treatment facilities, urgency of the shipment will decide if these castings should be heat treated for a limited time or for a complete cycle.

**Eutectic Melting** — If the heat treatment temperature is too high, so as to surpass the lower melting point of the alloys, the eutectic will melt. Eutectic melting can also be produced by too fast a rate of heating to the heat treatment temperature, even if the right temperature is not surpassed. This odd behaviour is due to the presence of segregations of zinc, which will cause the formation of the constituent MgZn, in the place of the ternary AlMgZn. The binary constituent, which should not be present, will form a eutectic with magnesium which has a melting point below the recommended heat treatment temperature. If the heat treatment is done by steps with a slow temperature rise, that constituent has time to be absorbed into solution and the low melting eutectic will not appear.

Eutectic melting is rather difficult to detect in mild cases. The mechanical properties are only slightly lower than usual and micro-examination will reveal only few spots (as the one in Fig. 19) which indicate either eutectic melting or porosity in the casting itself. In serious cases the casting starts to melt and even burns, and then it is a problem for the fireman rather than for the metallurgist! Castings in which eutectic melting has taken place cannot be salvaged other than by remelting.

*Fig. 18 — Incomplete Solution Caused by Too Low Temperature. The rounding of the constituents (especially of the pearlitic type of eutectic, here visible as black points) is typical of this defect. Also notice coring of the solid solution. Magnified 250 diameters; etched with 1% nital*

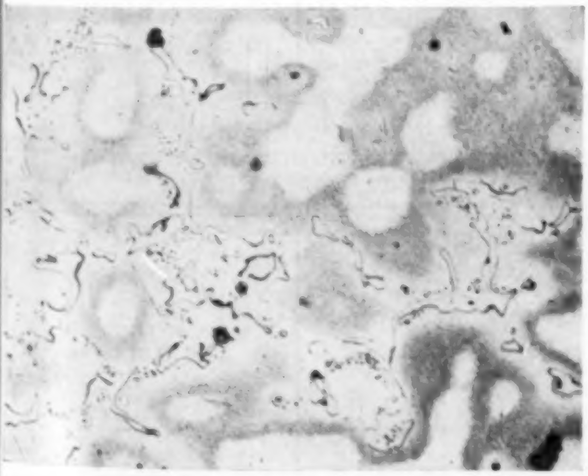


*Fig. 19 (Below) — Eutectic Melting Has Caused the Dark Lines and Spots Visible in This Casting. Magnified 100 diameters; glycol etch*

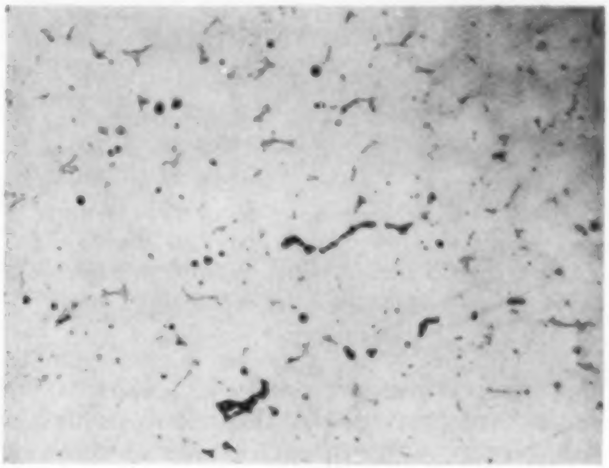


*Fig. 20 — High Temperature Deterioration Along Micro-Shrinkage Cracks Is Revealed by the Yellowish-Brown Oxides in the Print. Magnified 100 diameters; not etched*

**High Temperature Deterioration** — Another defect, which commonly is associated with eutectic melting under the common name "burning", is more properly called high temperature deterioration. The two defects are different as to aspect and, although they are sometimes associated, arise from different causes. Figure 20 shows the microstructure of a casting in which high temperature deterioration has taken place.

Serious cases can be detected also by visual examination as a blackened zone on the casting. Also, the fracture will reveal it. Figure 21 shows two spots where high temperature deterioration has gone almost through a casting. It tends to follow micro-shrinkage since the effect is a corrosion effect, caused by the oxidation of porous material by the air entrapped therein.

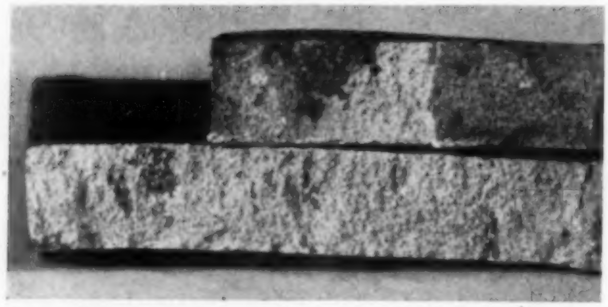


*Fig. 21 — Severe Cases of High Temperature Deterioration, as Shown by the Blackened Spots Inside the Casting. (Darker zone in the right of upper piece is a hot-short crack)*

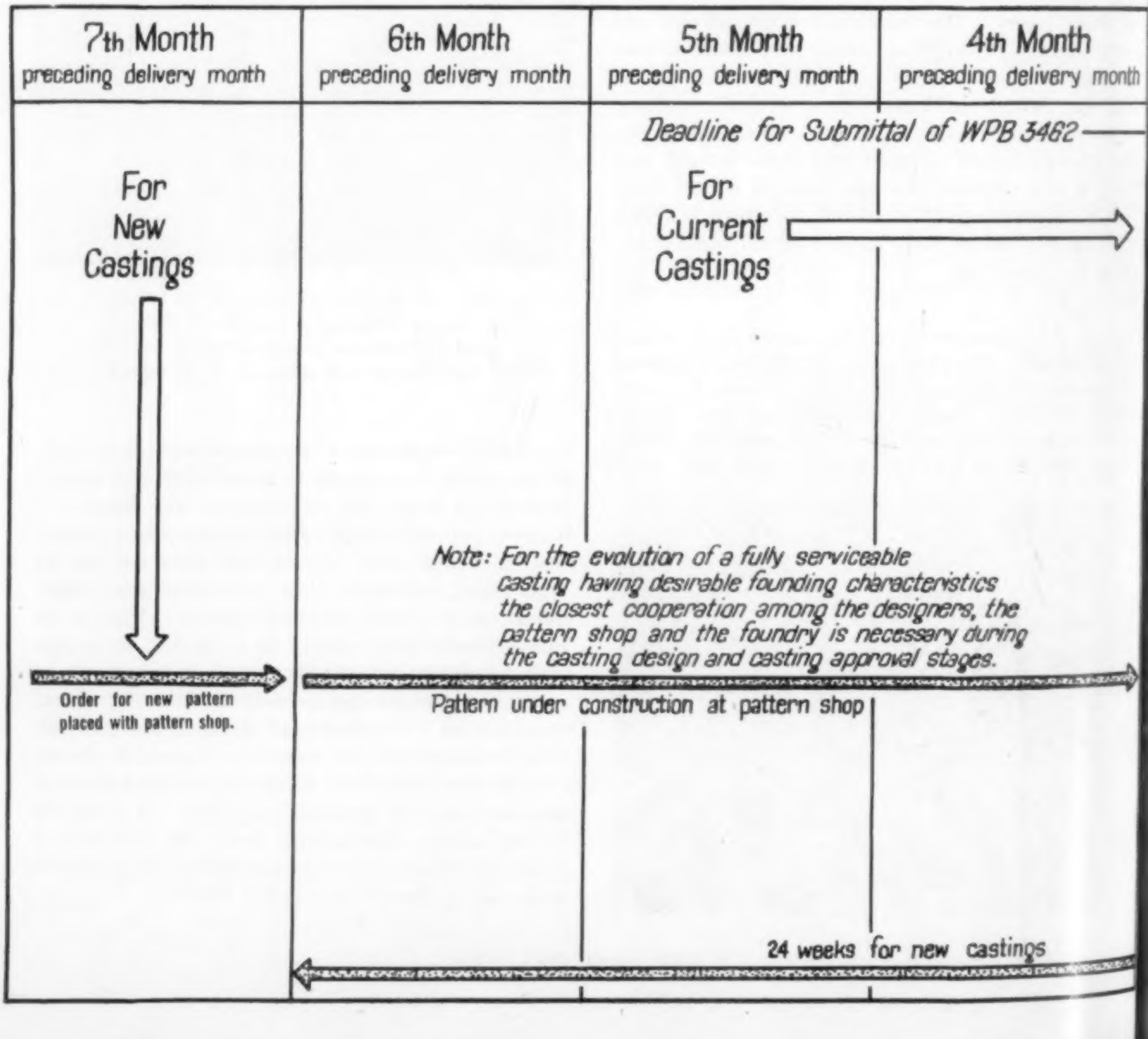
X-rays are of little use in the detection of high temperature deterioration, because it is impossible to distinguish it from micro-shrinkage.

**Warpage** — Magnesium castings at the heat treatment temperature are quite soft and if not carefully placed on racks will tend to settle. If warpage is serious, it may be necessary to resort to an annealing-straightening operation before the solution treatment.

**Grain Growth** — Magnesium alloys are rather susceptible to grain growth. As in steel and other alloys, a "critical" combination of plastic deformation (which need not be very great) and temperature will cause the formation of very large grains. Cold working followed by heating, as for instance cold straightening before solution heat treatment, may cause grains to grow even to 1 or 2 in. in diameter. Figure 22 shows an instance where cold work has produced twinning and grain growth. Grain growth may also occur on areas drastically chilled in the mold, when subsequently heat treated. Furthermore it will occur more readily in alloys high in aluminum, which require higher solution temperatures.

**Conclusion** — Our aim in these two contributions has been to describe those defects which are so common, both in frequency and in quantity, as

## Time Cycle for Procurement of Typical Airc



to constitute a problem from a production point of view. Many more defects may be found in magnesium castings, but it would be useless to try in these pages to expound the whole metallurgy of magnesium.

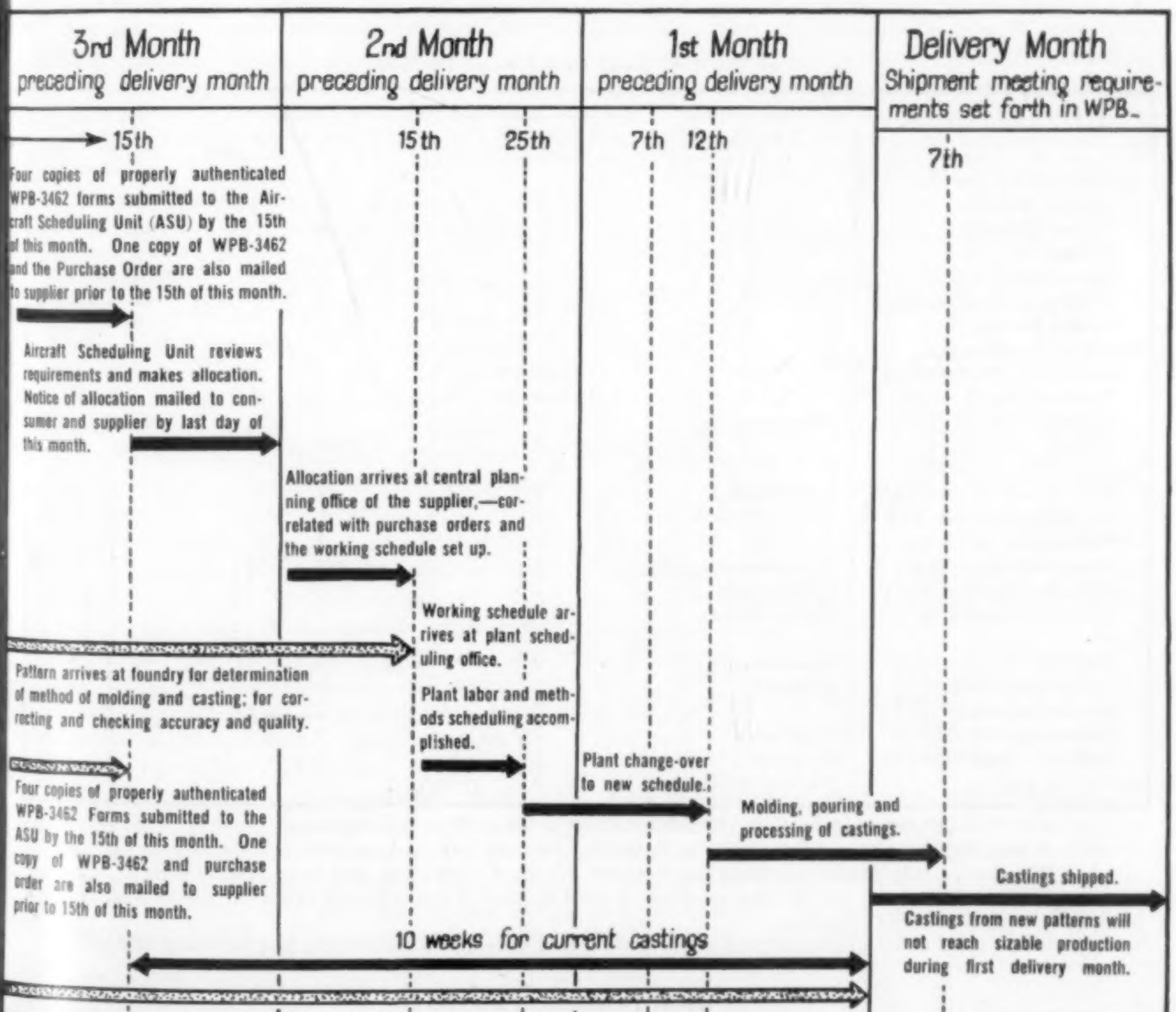
We hope that this paper will prove useful to those people who are now engaged on production of magnesium castings, and cannot take time out to investigate defects at their leisure, but must correct them as soon as they appear, and keep the castings flowing to the assembly lines.

We also hope that this emphasis on number and variety of defects will not create the impression that magnesium castings are inherently unreliable and should be avoided. Most of them are serious during the days when a new organization is learning how to cast these new alloys, strange in many respects. As was shown in Dr. Krivobok's article last month (page 1110) foundry rejects rapidly dropped as experience in production was gained.

*Fig. 22 — Casting Badly Distorted and Straightened Before Heating, Resulting in Coarse Grains, Slip Lines and Strain Bands. Magnified 25 diameters; etched with 1% nital*

## ...tings of Magnesium Alloy, Weighing Over 5 Lb.

By Allied Aircraft Production Board (Scheduling Unit) Wright Field, Dayton, Ohio



# Selection of Die Castings

WHILE discussing the "Post-War Outlook for Zinc Alloy Die Castings" before the April meeting of the American Zinc Institute, S. E. Maxon of New Jersey Zinc Sales Co. presented the attached interesting table. In it he ranks the four principal families in an approximate order of merit. In using it as a selector, the engineer should give prime consideration to the properties that *must* be secured, and the conditions that *must* be met. *Desirable* properties should then be given attention.

"Generally speaking, zinc alloy die castings give lowest overall cost, because of the many favorable properties by which they have gained widest use by a 3 to 1 margin over all others combined. Magnesium or aluminum alloys are commonly chosen when light weight is essential, and the brass alloys are chosen chiefly where a maximum in mechanical properties is demanded or where exceptional corrosion resistance is needed, since costs are rather high.

"Zinc alloys weigh about 2½ times as much as aluminum alloys, and under some market conditions the metal going into a given casting costs less in aluminum than in zinc alloy. Yet over a period of several years the *total* cost of zinc alloy castings has been nearly always well below that for an identical casting in aluminum alloy. The reason lies largely in the higher die maintenance and casting costs for the aluminum alloy, although other factors such as easier plating and the higher strength of the zinc alloys also influence its choice. Furthermore, because of their higher melting temperature, aluminum castings require a longer cooling period in the dies, and this slows down production rates."

**Order of Merit of Four Families of Die Castings**

| Selection Factor | Zinc Alloys A.S.T.M. 21, 23, 25 | Aluminum Alloys A.S.T.M. 5, 7, 12 | Magnesium Alloys A.S.T.M. 12, 13 | Copper Alloys (Brass) |
|---|---|---|---|---|
| *Mechanical Properties* | | | | |
| Tensile strength | 2 | 3 | 3 | 1 (strongest) |
| Impact strength | 2 | 3 | 3 | 1 (toughest) |
| Elongation | 2 | 4 | 3 | 1 (most ductile) |
| Dimensional stability | 3 *(a)* | 2 | 3 | 1 (most stable) |
| Resistance to cold flow | 3 | 2 | 2 | 1 (most resistant) |
| Brinell hardness | 2 | 3 | 3 | 1 (hardest) |
| *Physical Constants* | | | | |
| Electrical conductivity | 2 | 1 (highest) | 3 | 2 |
| Thermal conductivity | 3 | 1 (highest) | 4 | 2 |
| Melting point *(b)* | 1 (lowest) | 2 | 2 | 3 (highest) |
| Weight, per cu.in. | 3 | 2 | 1 (lightest) | 4 |
| *Casting Characteristics* | | | | |
| Ease, speed of casting | 1 (easiest) | 2 | 2 | 3 |
| Maximum feasible size | 1 | 1 | 1 | 2 |
| Complexity of shape | 1 | 1 | 1 | 2 |
| Dimensional accuracy | 1 (most accurate) | 2 | 2 | 3 |
| Least section thickness | 1 (thinnest) | 2 | 2 | 3 |
| Surface smoothness | 1 (smoothest) | 2 | 2 | 3 |
| *Cost* | | | | |
| Die cost *(c)* | 1 (lowest) | 2 | 2 | 3 |
| Production cost | 1 (lowest) | 2 | 2 | 3 |
| Machining cost | 1 | 2 | 1 | 3 |
| Finishing cost *(d)* | 1 (lowest) | 3 | 3 | 2 |
| Cost per piece *(e)* | 1 (lowest) | 2 | 2 | 3 |
| *Extent of Use* | 1 (most used) | 2 | 3 | 4 |

*(a)* A low temperature annealing virtually stabilizes Alloy 23 in dimensions.

*(b)* A low melting point is favorable in reducing die cost and upkeep and facilitates casting.

*(c)* Dies for casting the low melting point alloys are least expensive and have longest life.

*(d)* Includes polishing and buffing expense as well as ease of applying all types of commercial finishes, both electrodeposited and organic.

*(e)* Based on die, material and fuel costs, production speed, and machining and finishing costs.

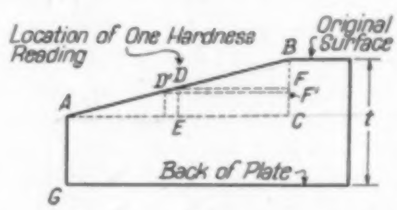
# Measurement of Case Depth by Hardness Gradient

By Thomas C. Fazio
Metallurgist, Armor Division
Breeze Corporations, Inc.
Newark, N. J.

CASE DEPTHS of carburized steels are usually obtained by carbon analyses of successive individual lathe or miller cuts which vary from 0.005 to 0.015 in. deep. This laboratory method, applied to both flat and round stock, is the most accurate and direct means of measuring carbon penetration.

In our laboratories where a great many such determinations are required, the above method proved tedious. Our investigations of carburization characteristics of armor plate analyses, as affected by temperature, composition of carburizing media, energizers, and other factors, resulted in such a large number of tests that a rapid method of case depth measurement was desired. Either visual or microscopic examinations of etched samples were only qualitative, and subject to inaccuracies due to the unpredictable behaviour of an etchant. A hardness gradient of a taper-ground specimen, hardened in a standardized manner, was found to be adequate, since it affords rapid, accurate and comparative results.

Hardness gradient is obtained in very simple fashion using the "photoslope" method. This involves measuring the Rockwell "C" hardness on a sloping plane which is ground at a small angle to the original surface. Any point on the slope then represents a particular depth below the surface, the depth being a constant fraction of the distance between the point of impression and the intersection of the plane of the slope with the original face. In the testing operation, indentations are taken at intervals down the slope and the sloped surface photographed. The distance between each impression and the top of the slope is tabulated with the respective hardness value. The product of this distance and a derived constant gives the depth. The sketch below shows how this constant $k$ is derived, and is independent of the magnification or reduction of the photograph. Obviously, also, the standard taper-ground piece can be placed on a simple fixture with a verniered traverse, and hardness readings taken at uniform intervals representing any desired series of depths.




In the above sketch, showing the cross-section of the test piece, $AB$ and $BD$ are measured on the photograph. $BC$ is the difference between the original thickness $t$ and the micrometered distance $AG$. We wish to know the depth below the original surface of the hardness impression $D$, or the distance $BF$. From similar triangles we equate the ratios

$$\frac{BF}{BD} = \frac{BC}{AB} = k$$

Solving, $BF = k \cdot BD$

Likewise, $BF' = k \cdot BD'$; etc.

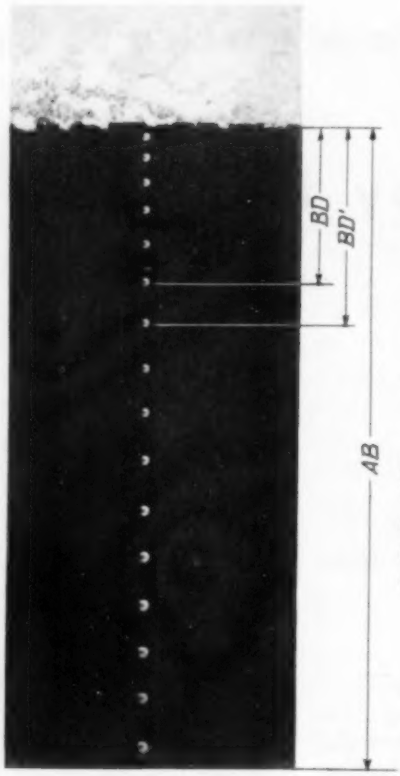
A photograph from one of the tests is shown on page 90; significance of the notation is obvious. Any number of parallel rows may be taken on one sample depending upon the precision required. For the above method a fixture for grinding is desirable, and a base with similar

taper is necessary for the hardness tester, where accurate values are important. The hardness fixture's base is ground at an angle such that the standard penetrator is perpendicular to the surface being tested.

The final test piece measures approximately ¾ in. wide and 2 in. long. To avoid an edge effect, a 9x9-in. plate is carburized. This plate size is also necessary so that a constant mass action effect will occur during quenching. The plate is thoroughly grit blasted, copper plated on one side and carburized for the desired length of time. We then normalize (air cool) from carburizing temperature, reheat in a neutral salt bath furnace and quench in oil at 130° F.

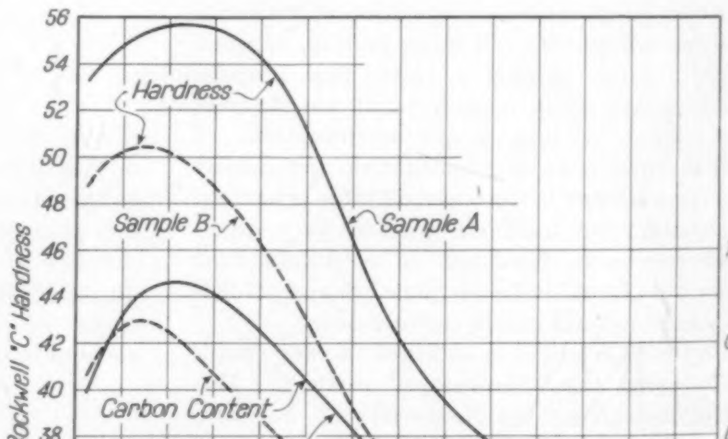
After hardening, a 2½-in. square is cut from one of the bottom corners. Two ½-in. edge strips are discarded, leaving enough material for the hardness gradient sample (½x2 in.), and a carbon gradient sample (1½x2 in.) if required. All cutting is done on a wet Carborundum wheel. With the aid of a tapered fixture as a base, to give the required angle of approximately 4°, the hardness specimen is surfaced on a surface grinder (magnetic chuck type, run wet) to cut 0.15 to 0.16 in. deep, or slightly beyond the total case depth, whatever it may be. This is an important step. A few thousandths are cut at one time to prevent overheating.

To orient our tests a number of samples, representing mean and extreme conditions, were surveyed for hardness penetration as described, and the results correlated with carbon analyses of thin layers cut parallel to the carburized surfaces. Two typical hardness gradients are shown in the accompanying graph. Comparing these with the carbon gradients, it is seen that the position of the maximum carbon is the same as for the maximum hardness; also the depth at which the hardness gradient tapers off checks well with the carbon-penetration curve. A considerable quantity of such evidence has taught us to rely upon the hardness test alone. The important characteristics we wish to know about a carburized case are *(a)* the depth at which the hump of the carbon gradient occurs *(b)* the depth at which the curve levels off, indicating the effective case.




*Photograph of a Hardness-Penetration Test Piece, Taper Ground and Tested at Intervals. Record made by projecting the image directly on bromide paper and developing; negative and reversal is unnecessary*

Hardness gradients have afforded us a rapid and accurate means of measuring case depths in carburized armor. Furthermore, they have been of value in detecting small amounts of retained austenite in high carbon cases, and, also, in the study of quenching characteristics. (It is planned to discuss these matters in a later communication.) The method can also be used to good advantage in determining the extent of decarburization for homogeneous and face hardened steels after they have gone through the various heat treating cycles.




*Comparative Gradients for Hardness and Carbon*

# Index of Uses for National Emergency Steels

Compiled by
**Research Dept.
Bethlehem Steel Co.**

*Alphabetical list by uses on pages 95 and 96. For chemical specifications and hardenabilities of NE steels see Data Sheet, page 96-B*

### NE 1320

Drive pinions
Ring gears

### NE 1330

Axle shafts
Bolts
Camshaft rocker levers
Cranes
Crankshaft forgings
Differential gears
Forgings, aircraft
Forgings, locomotive
Fuse wire
Grousers
Jigs, machine tools
Keys, machine tools
Link pins, doors, hatches
Pneumatic drill handles
Propeller shafts
Ring gears
Ship insulating cowls
Spindle shafts
Starting motor shafts
Steering knuckle supports
Studs, cylinder head
Tractor parts
Turbines
Vibration damping mountings

### NE 1335

Bolts, diesel engine
Chains
Cold headed or forged parts
Connecting rod bolts, diesel engine
Differential ring gears
Gear forgings
Keys, machine tools
Oil well sucker rods
Operating levers
Piston rods
Steering arms
Studs, auto
Wrenches

### NE 1340

Air brakes
Axle shafts, truck
Bevel gears
Carburetor parts
Chain appendages
Chain side bars
Compressor valves, mine
Cranes
Cylinder head studs
Diesel engine parts
Diesel lock ring bolts
Elevator shafts
Engine stand bolts
Fabrication nuts and bolts
Forgings, aircraft
Jack hammer bolts, mine
King pins, auto
Locomotive nuts
Milling cutter bodies
Nuts
Oil pump shafts, truck
Pinion gears
Rocker arms, aircraft
Screws; set screws
Shafts
Steering arms
Steering knuckles
Structural members
Studs
Tractor shafts
Transmission gears
Wrenches

### NE 1342

Transmission gears

### NE 1345

Axle shafts
Axles, trailer
Bevel gears
Bolts
Bolts, high temperature
Camshaft rocker levers
Cargo hoists
Chain, mine
Chain rollers
Chain terminals
Chemical tanks
Clutch shafts
Cold headed or forged
Collars, drill
Connecting rod bolts
Coupling bolts
Crankcase studs
Cracking still fittings
Crankshaft extension bolt
Dowel bushing
Draw bench mandrels and punches
Drill collars
Engine ring mounts
Engine spacers
Flame hardened objects
Forgings, aircraft
Hammers
Joints, oil well tool
Lever shafts
Lock nuts
Magneto coupling screw
Main bearing bolts
Nuts
Oil seal ring housing liner
Oil seal ring spacer
Oil well tool joints
Pinion shafts
Pinions and axles, mine
Piston rods
Screw machine parts
Screws
Spring cross shafts
Steering arms and knuckle supports
Studs, high temperature
Supercharger shaft
T-bolts
Transmission gears
Tread chains
Turbines
Valve spring collar key
Valve spring washers
Winch gears
Windlass shafts
Wrenches, tank

### NE 1350

Clutch spring bolt, auto
Conveyors
Drill stems
Flat springs
Gears
Hoist parts

### NE 1350 (Cont.)

Jack hammer valves
Retractor slides
Rock drill chucks, mine
Roller compression springs
Screws
Shafting
Shafts, machine tools
Springs, flat and leaf
Sprocket shafts
Steam pipe bolts
Steam turbine bolts
Tools, track
Tractor parts
Valve tappets
Yokes, shifter

### NE 8020

Armature pinions, mine
Boiler studs, locomotive
Chain knuckles and pins
Differential pinion gears
Drifter feed screws, mine
Handles
Jigs, machine tools
Piston pins
Pitman shafts
Pivot pins
Rifle bars, mine
Rock drill chucks, cylinder covers, hose connections, throttles and reamers
Shafts, main transmission
Side gears
Steering arm bolts, studs
Steering ball joints
Tooth followers
Transmission gears
Tread chains
Turret lathe collets
Valve tappets

### NE 8022

Boiler studs, locomotive
Chain knuckles and pins
Differential pinion gears
Drifter feed screws, mine
Drive pinions
Jigs, machine tools
Pipe wrench handles
Piston and pivot pins
Precision lathe parts
Rims, wheel
Rock drill parts (see NE 8020)
Shafts, main transmission
Shafts, pump
Side gears
Springs, leaf
Steering ball joints
Studs, steering arms
Tools
Transmission gears
Tread chains
Turret lathe collets
Valve tappets

### NE 8339

Axle shafts
Connecting rod bolts, diesel engine
Milling cutter bodies
Piston rods
Rock drill chucks, mine
Studs, automobile
Wrenches

### NE 8615

Tractor gears

### NE 8620

Armature pinions, mine
Automobile bolts
Bakery equipment
Bearings, races and balls
Bolts
Brake assemblies
Camshafts
Chain pins
Chuck parts
Clutch fork lever pin
Collets, machine tools
Cranes
Crankshaft forgings
Diesel engine hubs
Differential gears, pinions and ring gears
Drifter chucks, mine
Drive pinions
Gears, for mining and road machinery
Jigs, machine tools
King bolts and pins
Knuckle pins
Machinery, mine
Main drive gear
Oil pump impeller shafts
Pinion gears
Piston pins
Pneumatic tools
Precision lathe parts
Reducing gears
Reverse gear lock ring
Reverse gear pinion shaft
Ring gears
Rock drill bolts, mine
Rotor nuts
Shafts, mine
Shoes, mine
Side gears
Slides, machine tools
Splines
Sprockets, mine
Spring hanger pins
Starter motor drive shaft
Starter motor pinion
Steering arms, automobile
Steering ball joints
Suction pump impeller
Transmission chains
Transmission machinery
Valve tappets
Vibration damper
Worm gears and shafts

### NE 8630

Axle shafts
Bolts, diesel engine
Connecting rod bolts, diesel engine
Cranes
Dampener mountings
Fluid line fittings
Forgings, locomotive
Fuel pump sleeves
Jigs, machine tools
Keys, machine tools
King bolts
Link pins, doors, hatches
Piston rods
Spindle shafts
Starting motor armature shaft
Steering knuckle supports
Studs
Tractor parts
Tripods
Turbines

### NE 8635

Chain appendages
Chain pins
Cold headed or forged
Keys, machine tools
Oil well sucker rods
Operating levers
Pinion gears
Socket wrenches
Steering arms

### NE 8637

Diesel engines
Locomotive nuts
Reducing gears
Steering knuckles

### NE 8640

Air brakes
Axle shafts, truck
Axles
Bevel gears
Bolts
Bolts, high temperature
Carburetor parts
Centrifuges
Chain rollers; side bars
Chemical tanks
Clam bucket teeth
Cold headed or forged
Collars, drill
Connecting rod bolts
Coupling bolts
Cracking still fittings
Cranes
Crankcase studs
Crankshaft extension bolt
Diesel lock ring bolts
Dowel bushing
Drill collars
Elevator shafts
Flame hardened objects
Forgings, aircraft
Hexagonal nuts
Magneto drive, coupling screw
Main bearing bolts
Nuts
Oil seal ring housing liner
Oil seal ring spacer
Oil well tool joints
Pinion shafts
Piston rods
Pump rotors
Screws
Set screws
Shafting
Steering arms
Studs, high temperature
Tractor shafts
Transmission gears
Transmission machinery
Transmission sprockets
Tread chains
Turbines
Universal joints
Valve spring collar key
Windlass shafts
Wrenches, tank

### NE 8642

Cargo hoists
Clutch shafts
Draw bench mandrels and punches
Drill collars
Kelleys
Spring cross shafts
Transmission main shaft gear

### NE 8645

Axles, trailer
Clutch shafts; clutch spring bolt, automobile
Differential ring gears
Drill stems
Lever shafts
Roller compression springs
Shafting
Springs, flat and leaf
Sprocket shafts
Steam pipe bolts
Steam turbine bolts
Steering arms
Tools, aircraft
Tools, track
Valve tappets

### NE 8647

Tool holder studs

### NE 8650

Axles
Conveyors
Generator shafts
Hammers
Launch gears
Piston pins
Shafting

## NE 8715

Brake assemblies for automobiles
Cam shafts
Clutch fork lever pins for automobiles
Clutch pinion
Diesel engine hubs
Differential gears, pinion gears, ring gears
Drifter chucks, mine
Drive pinions
Forgings, aircraft
Gears for road rollers
Gears, mine
Gears, miscellaneous
King pins
Oil pump impeller shafts
Oil suction impeller
Pinion gears
Piston pins, diesel engine
Piston rings
Power boat transmission
Reducing gears
Reverse gear lock ring
Reverse gear pinion shaft
Rock drill hose connections and throttles
Rods, sucker
Slides, machine tools
Splines
Starter drives, motor drive shafts and pinions
Tool holder shanks
Tools, aircraft
Tractor gears
Transmission reverse gear
Vibration damper
Windlass
Worm shafts

## NE 8720

Balls, bearing
Bakery equipment
Bearings and races
Camshafts
Clutch driver and ring
Clutch forgings
Cranes
Crankshaft forgings
Differential gears
Differential ring gears
Drifters, drifter chucks and jaws
Drive pinions
Gears
King bolts and pins
Oil well sucker rods
Piston pins
Pivot pins
Ring and side gears
Splines
Steering ball joints
Stud and collar
Universal joints, truck
Transmission gears
Valve tappets

## NE 8722

Rods, sucker
Transmission main shaft

## NE 8724

Ball bearings
Differential gears

## NE 8730

Aircraft parts
Ring gears
Rods, sucker
Steering knuckle supports
Wrenches

## NE 8735

Chain pins
Cold headed or forged
Steering arms

## NE 8737

Compressor valves, mine
Jack hammer bolts, mine
Landing gear collars

## NE 8739

Axle pins and nuts
Chain side bars
Engine stand bolts
Fabrication and erection bolts and nuts
Herringbone pinions
Milling cutter bodies
Nuts
Pins
Pneumatic drill spindles and pumps
Reducing gears
Rock drill bolts, mine
Transmissions
Worm shafts

## NE 8740

Axle shafts and axles
Bevel gears
Centrifuges
Clam bucket teeth
Diesel lock ring bolts
Excavating machines
Lock nuts
Oil pump shafts, truck
Oil well tool joints
Shafting
Steering arms
Steering knuckles and supports
Studs
Transmission gears

## NE 8744

Axle shafts, truck
Chain, rollers, terminals
Gears, machine tools
Machinery, mine
Pinions and axles, mine
Pivot pins, mine
Press tie bolts
Screw machine parts
Shafts, machine tools
Shafts, mine
Spring cross shafts
Sprockets, mine
Steam pipe bolts
Steam turbine bolts
Studs, cylinder head
Studs, main bearing
T-bolts
Valve spring washers
Winches & winch gears

## NE 8745

Axle shafts, truck
Hammers
Jack hammer valves, mine
Valve spring washers

## NE 8749

Drill collars
Hoist parts
Kelleys
Oil well tool joints
Rock drill feed screw
Shafts, machine tools

## NE 8750

Axles
Axles, trailer
Hoists
Shafting
Sprocket shafts
Tool holder studs

## NE 8949

Axle shafts, truck
Launch gears
Lifting jacks
Pinions and axles, mine
Rock drill parts

## NE 9255

Coil springs
Collets, machine tools
Connecting rod bolts, diesel engine
Flat springs
Lock washers
Mine bits
Shafts, axle
Socket wrenches
Springs, leaf
Sway bars
Tools, track

## NE 9260

Chisels
Clutch springs
Coil and flat springs
Lock washers
Mine bits
Punches
Pipe tools
Rock drill bolts, mine
Springs, leaf
Street car repairs
Sway bars
Tools, hand tools

## NE 9262

Axes
Chisels
Coil and flat springs
Hand tools
Sway bars

## NE 9415

Pinion gears

## NE 9420

Armature pinions, mine
Bearing balls and races
Bearings
Bakery equipment
Boiler studs, locomotive
Bolts, automobile
Brake assemblies
Camshafts
Chain knuckles and pins
Chuck parts
Clutch forgings, fork lever pins, pinions, roller housings
Collet blanks
Cranes
Diesel engine hubs
Drive pinions
Differential gears, pinion gears, ring gears
Drifter chucks, feed screws
Forgings, aircraft
Gears
Handles
Jigs, machine tools
King bolts and pins
Knuckle pins
Motor nuts
Oil pump impeller shafts
Oil suction pump impeller
Oil well sucker rods
Pinions, mine
Piston pins, diesel engine
Piston rings
Pitman shafts
Pivot pins
Pneumatic tools
Power boat transmissions
Precision lathe parts
Pump shafts
Reducing gears
Reverse gear lock ring
Reverse gear pinion shaft
Ring gears
Rock drill parts, chucks, cylinder covers, hose connections and throttles, reamers
Roller bearings
Shafts, main transmission
Shafts, mine
Shoes, mine
Side gears
Slides, machine tools
Splines
Spring hanger pins

Springs, leaf
Sprockets, mine
Steering arm, bolts, studs
Steering ball joints
Tool holder shanks
Tools
Tooth followers
Tractor gears
Transmission gears
Transmission machinery
Tread chains and pins
Turret lathe collets
Universal joints, truck
Valve tappets
Vibration damper
Winches
Windlass
Worm gears and shafts

### NE 9422

Clutch body
Clutch driver and ring
Differential gears, pinion gears, ring gears
Drifters, drifter chucks and jaws
Drive pinions
Gears
Oil well sucker rods
Pipe wrench handles
Shafts, pump
Starter drives
Studs, steering arms
Tread chains

### NE 9430

Axle shafts
Boiler studs, locomotive
Bolts, diesel engine
Bolts, high temperature
Camshaft rocker levers
Connecting rod bolts, diesel engine
Cranes
Crankshaft forgings
Dampener mountings
Differential gears
Fluid line fittings
Forgings, aircraft
Forgings, locomotive
Jigs, machine tools
Keys, aircraft
Keys, machine tools
Link pins, doors, latches
Milling cutter bodies
Oil pump piston assemblies
Piston rods
Pneumatic drill handles
Ring gears
Spindle shafts
Studs, automobile
Tools, aircraft
Tractor parts
Tripods
Turbines
Valves
Wrenches

### NE 9435

Bevel gears
Chain appendages, pins
Cold headed or forged
Differential ring gears
King pins
Oil well sucker rods
Operating levers
Pinion gears
Socket wrenches
Steering arms, knuckles
Tractor shafts

### NE 9437

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Diesel engines
Forgings, aircraft
Jack hammer bolts, mine
Locomotive nuts
Pneumatic drill spindles and pumps
Reducing gears
Transmission gears
Worm shafts

### NE 9440

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Axles
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Camshaft rocker levers
Carburetor parts
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Chain rollers, side bars
Chemical tanks
Clam bucket teeth
Collars, drill
Cold headed or forged
Connecting rod bolts
Coupling bolts
Cracking still fittings
Cranes and crane pins
Crankcase studs
Crankshaft extension bolt
Cylinder head studs
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Drill collars
Engine spacers
Engine stand bolts
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Excavating machines
Fabrication bolts
Flame hardened objects
Forgings, aircraft
Gears
Herringbone pinions
Hexagonal nuts, lock nuts
Magneto coupling screw
Main bearing bolts
Oil seal ring housing liner
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Oil well tool joints
Pinions and axles, mine
Pinion shafts
Piston rods
Propeller shafts
Scythe blades
Steering arms
Steering knuckle supports
Studs, high temperature
Tool joints
Transmission gears, sprockets and parts
Tread chains
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Windlass shafts
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### NE 9442

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Cargo hoists
Chain and chain terminals
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Shafts, mine
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Spring cross shafts
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### NE 9445

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Pump piston rods
Ring gears
Rock drill chucks, mine
Roller compression springs
Screw machine parts
Shafting
Shafts, machine tools
Springs, flat and leaf
Steam pipe bolts
Steam turbine bolts
Steering arms
Sprocket shafts
T-bolts and nuts
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Tools, track
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Valve tappets
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### NE 9450

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Axles, trailer
Chisels
Collets, machine tools
Conveyors
Generator shafts
Hoist parts
Impeller gears
Launch gears
Pinions and axles, mine
Pinions, drive
Piston pins
Pliers
Rock drill parts
Socket wrenches
Sprocket shafts
Tool holder studs
Winches
Worm gears
Wrenches

### NE 9460

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### NE 9537

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Rockers

### NE 9540

Anchor winch
Axle shafts
Chain hoists
Compressor connecting rod bolts, mine
Die blocks for rock drill sharpeners
Dies
Drum shafts
Excavating machines
Gear shafts
Hot saw turrets
Link pins for tractors
Milling cutter bodies
Pipe wrench jaws
Pump rotors
Rock drill chuck nuts
Rock drill chucks, mine
Rock drill parts
Stoker parts
Winch shaft
Wing hinge fittings

### NE 9550

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Rock drill feed screws
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# National Emergency Alloy Steels*

**Openhearth Alloy and Electric Furnace Alloy Steels; Blooms, Billets, Slabs, Bars and Hot Rolled Strip.** *Revised May 26, 1944*

| Adopted | Aban-doned | Desig-nation | C | Mn | Si (a) | Ni | Cr | Mo | Hardenability (b) Low | Hardenability (b) High |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Carbon-Manganese Steels** | | | | | | | | |
| 8/17/42 | | NE1330 | 0.28-0.33 | 1.60-1.90 | 0.20-0.35 | (c) | (d) | (e) | 1.53 | 4.24 |
| 8/17/42 | | NE1335 | 0.33-0.38 | 1.60-1.90 | 0.20-0.35 | (c) | (d) | (e) | 1.67 | 4.54 |
| 8/17/42 | | NE1340 | 0.38-0.43 | 1.60-1.90 | 0.20-0.35 | (c) | (d) | (e) | 1.80 | 4.79 |
| 8/17/42 | | NE1345 | 0.43-0.48 | 1.60-1.90 | 0.20-0.35 | (c) | (d) | (e) | 1.91 | 5.10 |
| 8/17/42 | | NE1350 | 0.48-0.53 | 1.60-1.90 | 0.20-0.35 | (c) | (d) | (e) | 2.02 | 5.39 |
| | | **Carbon-Chromium Steels (f)** | | | | | | | | |
| 8/17/42 | | NE52100 C | 0.95-1.10 | 0.25-0.45 | 0.20-0.35 | 0.35max. | 0.40-0.60 | 0.08max. | 1.19 | 4.0 |
| 8/17/42 | | NE52100 B | 0.95-1.10 | 0.25-0.45 | 0.20-0.35 | 0.35max. | 0.90-1.15 | 0.08max. | 1.74 | 6.0 (g) |
| 8/17/42 | | NE52100 A | 0.95-1.10 | 0.25-0.45 | 0.20-0.35 | 0.35max. | 1.30-1.60 | 0.08max. | 2.40 | 8.7 (g) |
| | | **Manganese-Molybdenum Steels** | | | | | | | | |
| 8/17/42 | 8/15/43 | NE8020 | 0.18-0.23 | 1.00-1.30 | 0.20-0.35 | | | 0.10-0.20 | | |
| 8/17/42 | 12/17/42 | NE8022 | 0.20-0.25 | 1.00-1.30 | 0.20-0.35 | | | 0.10-0.20 | | |
| 1/21/42 | 8/17/42 | NE8024 | 0.22-0.28 | 1.00-1.30 | 0.20-0.35 | | | 0.10-0.20 | | |
| 1/21/42 | 8/17/42 | NE8124 | 0.22-0.28 | 1.30-1.60 | 0.20-0.35 | | | 0.25-0.35 | | |
| 1/21/42 | 8/17/42 | NE8233 | 0.30-0.36 | 1.30-1.60 | 0.20-0.35 | | | 0.10-0.20 | | |
| 1/21/42 | 8/17/42 | NE8245 | 0.42-0.49 | 1.30-1.60 | 0.20-0.35 | | | 0.10-0.20 | | |
| 1/21/42 | 12/17/42 | NE8339 | 0.35-0.42 | 1.30-1.60 | 0.20-0.35 | | | 0.20-0.30 | | |
| 1/21/42 | 8/15/43 | NE8442 | 0.40-0.45 | 1.30-1.60 | 0.20-0.35 | | | 0.30-0.40 | | |
| 1/21/42 | 8/17/42 | NE8447 | 0.43-0.50 | 1.30-1.60 | 0.20-0.35 | | | 0.30-0.40 | | |
| 1/21/42 | 8/17/42 | NE8547 | 0.43-0.50 | 1.30-1.60 | 0.20-0.35 | | | 0.40-0.60 | | |
| | | **Nickel-Chromium-Molybdenum Steels** | | | | | | | | |
| 5/26/44 | | NE8612 | 0.10-0.15 | 0.70-0.90 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.15-0.25 | 1.07 | 3.68 |
| 8/17/42 | 5/26/44 | NE8613 | 0.12-0.17 | 0.70-0.90 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.15-0.25 | | |
| 8/17/42 | | NE8615 | 0.13-0.18 | 0.70-0.90 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.15-0.25 | 1.34 | 4.02 |
| 8/17/42 | | NE8617 | 0.15-0.20 | 0.70-0.90 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.15-0.25 | 1.43 | 4.25 |
| 1/21/42 | | NE8620 | 0.18-0.23 | 0.70-0.90 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.15-0.25 | 1.52 | 4.47 |
| 5/26/44 | | NE8622 | 0.20-0.25 | 0.70-0.90 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.15-0.25 | 1.65 | 4.77 |
| 5/26/44 | | NE8625 | 0.23-0.28 | 0.70-0.90 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.15-0.25 | 1.72 | 4.96 |
| 5/26/44 | | NE8627 | 0.25-0.30 | 0.70-0.90 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.15-0.25 | 1.84 | 5.23 |
| 1/21/42 | | NE8630 | 0.28-0.33 | 0.70-0.90 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.15-0.25 | 1.91 | 5.47 |
| 5/26/44 | | NE8632 | 0.30-0.35 | 0.70-0.90 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.15-0.25 | 2.00 | 5.64 |
| 12/17/42 | | NE8635 | 0.33-0.38 | 0.75-1.00 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.15-0.25 | 2.22 | 6.35 |
| 12/17/42 | | NE8637 | 0.35-0.40 | 0.75-1.00 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.15-0.25 | 2.28 | 6.50 |
| 12/17/42 | | NE8640 | 0.38-0.43 | 0.75-1.00 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.15-0.25 | 2.38 | 6.75 |
| 12/17/42 | | NE8642 | 0.40-0.45 | 0.75-1.00 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.15-0.25 | 2.44 | 6.90 |
| 12/17/42 | | NE8645 | 0.43-0.48 | 0.75-1.00 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.15-0.25 | 2.53 | 7.15 |
| 5/26/44 | | NE8647 | 0.45-0.50 | 0.75-1.00 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.15-0.25 | 2.59 | 7.35 |
| 12/17/42 | | NE8650 | 0.48-0.53 | 0.75-1.00 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.15-0.25 | 2.67 | 7.55 |
| 5/26/44 | | NE8712 | 0.10-0.15 | 0.70-0.90 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.20-0.30 | 1.30 | 4.01 |
| 5/26/44 | | NE8715 | 0.13-0.18 | 0.70-0.90 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.20-0.30 | 1.48 | 4.39 |
| 5/26/44 | | NE8717 | 0.15-0.20 | 0.70-0.90 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.20-0.30 | 1.58 | 4.63 |
| 5/26/44 | | NE8720 | 0.18-0.23 | 0.70-0.90 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.20-0.30 | 1.72 | 4.98 |
| 5/26/44 | | NE8722 | 0.20-0.25 | 0.70-0.90 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.20-0.30 | 1.82 | 5.20 |
| 1/21/42 | 8/17/42 | NE8724 | 0.22-0.28 | 0.70-0.95 | 0.20-0.35 | 0.40-0.60 | 0.40-0.60 | 0.20-0.30 | | |
| 5/26/44 | | NE8725 | 0.23-0.28 | 0.70-0.90 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.20-0.30 | 1.95 | 5.50 |
| 5/26/44 | | NE8727 | 0.25-0.30 | 0.70-0.90 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.20-0.30 | 2.03 | 5.70 |
| 5/26/44 | | NE8730 | 0.28-0.33 | 0.70-0.90 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.20-0.30 | 2.14 | 5.95 |
| 5/26/44 | | NE8732 | 0.30-0.35 | 0.70-0.90 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.20-0.30 | 2.22 | 6.15 |
| 5/26/44 | | NE8735 | 0.33-0.38 | 0.75-1.00 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.20-0.30 | 2.44 | 6.90 |
| 5/26/44 | | NE8737 | 0.35-0.40 | 0.75-1.00 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.20-0.30 | 2.52 | 7.05 |
| 1/21/42 | 12/17/42 | NE8739 | 0.35-0.42 | 0.75-1.00 | 0.20-0.35 | 0.40-0.60 | 0.40-0.60 | 0.20-0.30 | | |
| 5/26/44 | | NE8740 | 0.38-0.43 | 0.75-1.00 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.20-0.30 | 2.62 | 7.35 |
| 5/26/44 | | NE8742 | 0.40-0.45 | 0.75-1.00 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.20-0.30 | 2.70 | 7.50 |
| 1/21/42 | 12/17/42 | NE8744 | 0.40-0.47 | 0.75-1.00 | 0.20-0.35 | 0.40-0.60 | 0.40-0.60 | 0.20-0.30 | | |
| 5/26/44 | | NE8745 | 0.43-0.48 | 0.75-1.00 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.20-0.30 | 2.79 | 7.75 |
| 5/26/44 | | NE8747 | 0.45-0.50 | 0.75-1.00 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.20-0.30 | 2.86 | 7.95 |
| 1/21/42 | 12/17/42 | NE8749 | 0.45-0.52 | 0.75-1.00 | 0.20-0.35 | 0.40-0.60 | 0.40-0.60 | 0.20-0.30 | | |
| 5/26/44 | | NE8750 | 0.48-0.53 | 0.75-1.00 | 0.20-0.35 | 0.40-0.70 | 0.40-0.60 | 0.20-0.30 | 2.95 | 8.20 |
| 1/21/42 | 8/17/42 | NE8817 | 0.15-0.20 | 0.70-0.95 | 0.20-0.35 | 0.40-0.60 | 0.40-0.60 | 0.30-0.40 | | |
| 1/21/42 | 12/17/42 | NE8949 | 0.45-0.52 | 1.00-1.30 | 0.20-0.35 | 0.40-0.60 | 0.40-0.60 | 0.30-0.40 | | |

| Adopted | Aban-doned | Desig-nation | C | Mn | Si (a) | Ni | Cr | Mo | Hardenability (b) Low | Hardenability (b) High |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Silicon-Manganese and Silicon-Manganese-Chromium Steels** | | | | | | | | |
| 8/17/42 | | NE9255 | 0.50-0.60 | 0.70-0.95 | 1.80-2.20 | (c) | (d) | (e) | 2.30 | 6.60 |
| 8/17/42 | | NE9260 | 0.55-0.65 | 0.70-1.00 | 1.80-2.20 | (c) | (d) | (e) | 2.34 | 7.15 |
| 8/15/43 | | NE9261 | 0.55-0.65 | 0.70-1.00 | 1.80-2.20 | (c) | 0.10-0.25 | (e) | 2.60 | 9.20 |
| 8/17/42 | | NE9262 | 0.55-0.65 | 0.70-1.00 | 1.80-2.20 | (c) | 0.25-0.40 | (e) | 3.36 | 10.5 |
| | | **Manganese-Nickel-Chromium-Molybdenum Steels (h)** | | | | | | | | |
| 8/17/42 | | NE9415 | 0.13-0.18 | 0.80-1.10 | 0.20-0.35 | 0.30-0.60 | 0.30-0.50 | 0.08-0.15 | 1.15 | 3.52 |
| 5/26/44 | | NE9417 | 0.15-0.20 | 0.80-1.10 | 0.20-0.35 | 0.30-0.60 | 0.30-0.50 | 0.08-0.15 | 1.23 | 3.70 |
| 8/17/42 | | NE9420 | 0.18-0.23 | 0.80-1.10 | 0.20-0.35 | 0.30-0.60 | 0.30-0.50 | 0.08-0.15 | 1.34 | 3.99 |
| 8/17/42 | | NE9422 | 0.20-0.25 | 0.80-1.10 | 0.20-0.35 | 0.30-0.60 | 0.30-0.50 | 0.08-0.15 | 1.42 | 4.17 |
| 8/15/43 | | NE9425 | 0.23-0.28 | 0.90-1.20 | 0.20-0.35 | 0.30-0.60 | 0.30-0.50 | 0.08-0.15 | 1.66 | 4.72 |
| 5/26/44 | | NE9427 | 0.25-0.30 | 0.90-1.20 | 0.20-0.35 | 0.30-0.60 | 0.30-0.50 | 0.08-0.15 | 1.72 | 4.89 |
| 8/17/42 | | NE9430 | 0.28-0.33 | 0.90-1.20 | 0.20-0.35 | 0.30-0.60 | 0.30-0.50 | 0.08-0.15 | 1.81 | 5.10 |
| 5/26/44 | | NE9432 | 0.30-0.35 | 0.90-1.20 | 0.20-0.35 | 0.30-0.60 | 0.30-0.50 | 0.08-0.15 | 1.88 | 5.25 |
| 8/17/42 | | NE9435 | 0.33-0.38 | 0.90-1.20 | 0.20-0.35 | 0.30-0.60 | 0.30-0.50 | 0.08-0.15 | 1.98 | 5.45 |
| 8/17/42 | | NE9437 | 0.35-0.40 | 0.90-1.20 | 0.20-0.35 | 0.30-0.60 | 0.30-0.50 | 0.08-0.15 | 2.03 | 5.60 |
| 8/17/42 | | NE9440 | 0.38-0.43 | 0.90-1.20 | 0.20-0.35 | 0.30-0.60 | 0.30-0.50 | 0.08-0.15 | 2.12 | 5.80 |
| 8/17/42 | | NE9442 | 0.40-0.45 | 1.00-1.30 | 0.20-0.35 | 0.30-0.60 | 0.30-0.50 | 0.08-0.15 | 2.36 | 6.50 |
| 8/17/42 | | NE9445 | 0.43-0.48 | 1.00-1.30 | 0.20-0.35 | 0.30-0.60 | 0.30-0.50 | 0.08-0.15 | 2.45 | 6.75 |
| 5/26/44 | | NE9447 | 0.45-0.50 | 1.20-1.50 | 0.20-0.35 | 0.30-0.60 | 0.30-0.50 | 0.08-0.15 | 2.90 | 8.05 |
| 8/17/42 | | NE9450 | 0.48-0.53 | 1.20-1.50 | 0.20-0.35 | 0.30-0.60 | 0.30-0.50 | 0.08-0.15 | 2.99 | 8.30 |
| | | **Manganese-Silicon-Nickel-Chromium-Molybdenum Steels** | | | | | | | | |
| 8/17/42 | 5/26/44 | NE9537 (i) | 0.35-0.40 | 1.20-1.50 | 0.40-0.60 | 0.40-0.70 | 0.40-0.60 | 0.15-0.25 | | |
| 8/17/42 | 5/26/44 | NE9540 (i) | 0.38-0.43 | 1.20-1.50 | 0.40-0.60 | 0.40-0.70 | 0.40-0.60 | 0.15-0.25 | | |
| 8/17/42 | 5/26/44 | NE9542 (i) | 0.40-0.45 | 1.20-1.50 | 0.40-0.60 | 0.40-0.70 | 0.40-0.60 | 0.15-0.25 | | |
| 8/15/43 | 5/26/44 | NE9545 (i) | 0.43-0.48 | 1.20-1.50 | 0.40-0.60 | 0.40-0.70 | 0.40-0.60 | 0.15-0.25 | | |
| 8/17/42 | 5/26/44 | NE9550 (i) | 0.48-0.53 | 1.20-1.50 | 0.40-0.60 | 0.40-0.70 | 0.40-0.60 | 0.15-0.25 | | |
| | | **Manganese-Silicon-Chromium Steels** | | | | | | | | |
| 8/17/42 | 8/15/43 | NE9630 | 0.28-0.33 | 1.20-1.50 | 0.40-0.60 | | 0.40-0.60 | | | |
| 8/17/42 | 8/15/43 | NE9635 | 0.33-0.38 | 1.20-1.50 | 0.40-0.60 | | 0.40-0.60 | | | |
| 8/17/42 | 8/15/43 | NE9637 | 0.35-0.40 | 1.20-1.50 | 0.40-0.60 | | 0.40-0.60 | | | |
| 8/17/42 | 8/15/43 | NE9640 | 0.38-0.43 | 1.20-1.50 | 0.40-0.60 | | 0.40-0.60 | | | |
| 8/17/42 | 8/15/43 | NE9642 | 0.40-0.45 | 1.30-1.60 | 0.40-0.60 | | 0.40-0.60 | | | |
| 8/17/42 | 8/15/43 | NE9645 | 0.43-0.48 | 1.30-1.60 | 0.40-0.60 | | 0.40-0.60 | | | |
| 8/17/42 | 8/15/43 | NE9650 | 0.48-0.53 | 1.30-1.60 | 0.40-0.60 | | 0.40-0.60 | | | |
| | | **Nickel-Molybdenum Steels (j)** | | | | | | | | |
| 5/26/44 | | NE9722 | 0.20-0.25 | 0.50-0.80 | 0.20-0.35 | 0.40-0.70 | 0.10-0.25 | 0.15-0.25 | 0.90 | 3.31 |
| 5/26/44 | | NE9727 | 0.25-0.30 | 0.50-0.80 | 0.20-0.35 | 0.40-0.70 | 0.10-0.25 | 0.15-0.25 | 1.00 | 3.63 |
| 5/26/44 | | NE9732 | 0.30-0.35 | 0.50-0.80 | 0.20-0.35 | 0.40-0.70 | 0.10-0.25 | 0.15-0.25 | 1.09 | 3.92 |
| 5/26/44 | | NE9737 | 0.35-0.40 | 0.50-0.80 | 0.20-0.35 | 0.40-0.70 | 0.10-0.25 | 0.15-0.25 | 1.18 | 4.16 |
| 5/26/44 | | NE9742 | 0.40-0.45 | 0.50-0.80 | 0.20-0.35 | 0.40-0.70 | 0.10-0.25 | 0.15-0.25 | 1.27 | 4.42 |
| 5/26/44 | | NE9745 | 0.43-0.48 | 0.50-0.80 | 0.20-0.35 | 0.40-0.70 | 0.10-0.25 | 0.15-0.25 | 1.31 | 4.57 |
| 5/26/44 | | NE9747 | 0.45-0.50 | 0.50-0.80 | 0.20-0.35 | 0.40-0.70 | 0.10-0.25 | 0.15-0.25 | 1.34 | 4.68 |
| 5/26/44 | | NE9750 | 0.48-0.53 | 0.50-0.80 | 0.20-0.35 | 0.40-0.70 | 0.10-0.25 | 0.15-0.25 | 1.39 | 4.84 |
| 5/26/44 | | NE9763 | 0.60-0.67 | 0.50-0.80 | 0.20-0.35 | 0.40-0.70 | 0.10-0.25 | 0.15-0.25 | 1.55 | 5.05 |
| 5/26/44 | | NE9768 | 0.64-0.72 | 0.50-0.80 | 0.20-0.35 | 0.40-0.70 | 0.10-0.25 | 0.15-0.25 | 1.60 | 4.65 |
| | | **Nickel-Chromium-Molybdenum Steels (k)** | | | | | | | | |
| 5/26/44 | | NE9830 (i) | 0.28-0.33 | 0.70-0.90 | 0.20-0.35 | 0.85-1.15 | 0.70-0.90 | 0.20-0.30 | 2.91 | 8.45 |
| 5/26/44 | | NE9832 (i) | 0.30-0.35 | 0.70-0.90 | 0.20-0.35 | 0.85-1.15 | 0.70-0.90 | 0.20-0.30 | 3.02 | 8.75 |
| 5/26/44 | | NE9835 (i) | 0.33-0.38 | 0.70-0.90 | 0.20-0.35 | 0.85-1.15 | 0.70-0.90 | 0.20-0.30 | 3.18 | 9.05 |
| 5/26/44 | | NE9837 (i) | 0.35-0.40 | 0.70-0.90 | 0.20-0.35 | 0.85-1.15 | 0.70-0.90 | 0.20-0.30 | 3.26 | 9.30 |
| 5/26/44 | | NE9840 (i) | 0.38-0.43 | 0.70-0.90 | 0.20-0.35 | 0.85-1.15 | 0.70-0.90 | 0.20-0.30 | 3.41 | 9.65 |
| 5/26/44 | | NE9842 (i) | 0.40-0.45 | 0.70-0.90 | 0.20-0.35 | 0.85-1.15 | 0.70-0.90 | 0.20-0.30 | 3.50 | 9.85 |
| 5/26/44 | | NE9845 (i) | 0.43-0.48 | 0.70-0.90 | 0.20-0.35 | 0.85-1.15 | 0.70-0.90 | 0.20-0.30 | 3.62 | 10.2 |
| 5/26/44 | | NE9847 (i) | 0.45-0.50 | 0.70-0.90 | 0.20-0.35 | 0.85-1.15 | 0.70-0.90 | 0.20-0.30 | 3.70 | 10.5 |
| 5/26/44 | | NE9850 (i) | 0.48-0.53 | 0.70-0.90 | 0.20-0.35 | 0.85-1.15 | 0.70-0.90 | 0.20-0.30 | 3.83 | 10.8 |
| | | **Triple Steels for Carburizing (l)** | | | | | | | | |
| 5/26/44 | | NE9912 | 0.10-0.15 | 0.50-0.70 | 0.20-0.35 | 1.00-1.30 | 0.40-0.60 | 0.20-0.30 | 1.23 | 3.92 |
| 5/26/44 | | NE9915 | 0.13-0.18 | 0.50-0.70 | 0.20-0.35 | 1.00-1.30 | 0.40-0.60 | 0.20-0.30 | 1.41 | 4.29 |
| 5/26/44 | | NE9917 | 0.15-0.20 | 0.50-0.70 | 0.20-0.35 | 1.00-1.30 | 0.40-0.60 | 0.20-0.30 | 1.50 | 4.52 |
| 5/26/44 | | NE9920 | 0.18-0.23 | 0.50-0.70 | 0.20-0.35 | 1.00-1.30 | 0.40-0.60 | 0.20-0.30 | 1.64 | 4.86 |
| 5/26/44 | | NE9922 | 0.20-0.25 | 0.50-0.70 | 0.20-0.35 | 1.00-1.30 | 0.40-0.60 | 0.20-0.30 | 1.74 | 5.10 |
| 5/26/44 | | NE9925 | 0.23-0.28 | 0.50-0.70 | 0.20-0.35 | 1.00-1.30 | 0.40-0.60 | 0.20-0.30 | 1.86 | 5.40 |

**Notes**

*All National Emergency Steels are subject to the conditions concerning chemical ranges and phosphorus and sulphur maxima as outlined for standard alloy steels on pages 14 to 17 inclusive in the latest revision of American Iron & Steel Institute's Steel Product Manual No. 10, entitled "Alloy Steels", and to the standard permissible variations from specified ranges as listed on page 26 of that Manual. Large sections are subject to modifications of carbon content only to a range of 0.10 (10 points); see page 23 of Manual No. 10.

Phosphorus and Sulphur Limits: When basic electric furnace steel is specified, phosphorus and sulphur limits are to be 0.025% max. each; for basic openhearth steel 0.040% max. each; for acid openhearth or electric steel 0.050% max. each. (These elements not used in computing hardenability.)

(a) For basic steel. Lowest minimum silicon limit to be specified for acid steel is 0.15%.

(b) Not part of the specifications. Computed by Grossmann's methods as outlined in "Metal Progress" Data Sheet No. 29, as modified by Crafts and Lamont, for grain sizes 8 and 5 (low and high side respectively).

(c) Supposedly none. Hardenability computations assume 0.10-0.25.

(d) Ditto. Assumed 0.05-0.10.

(e) Ditto. Assumed 0.00-0.08.

(f) NE52100 steels are for ball and roller bearings. Copper is limited to 0.25% max. in all analyses, and limits for inclusions are to be according to A.S.T.M. specification ES-5a.

(g) Doubtful, from unknown effect of undissolved carbides.

(h) NE9400 series, as established Aug. 17, 1942, had high-silicon (0.40-0.60%), and low nickel and chromium (0.20 to 0.40% each). Silicon, nickel and chromium were dropped to their present ranges on Aug. 15, 1943.

(i) For large sections only.

(j) NE9700 series has hardenability characteristics similar to A4000 series.

(k) NE9800 series includes deep hardening steels with hardenability between NE8700 and A4300 series.

(l) NE9900 series includes higher nickel carburizing steels with similar hardenability to NE8700.

## Maximum Carbon in Carburized Cases

CLEVELAND, OHIO

*To the Readers of* METAL PROGRESS:

The discrepancy between the careful work reported by Floyd E. Harris on the maximum carbon in carburized cases, and the equally careful work by Robert W. Schlumpf (see April *Metal Progress*, page 683), needs a little discussion. I would certainly hesitate to discourage the use of Schlumpf's results, especially in predicting the results of carburizing in solid compounds.

Mr. Harris finds that surface carbons in his pieces, carburized in simple gas atmosphere, correspond closely to that represented by the $A_{cm}$ line in the iron-carbon equilibrium diagram, and are the higher as the carburizing temperature goes up. Mr. Schlumpf finds, on the other hand, that S.A.E. 3115 carburized in sodium energized compounds had 3.10% carbon at its surface when carburized at 1500° F., 1.8% carbon when carburized at 1600° F., and about 1.2% carbon when carburized at higher temperatures. (There is no discrepancy in the results of these two investigators concerning the carbon-penetration curves *below* the surface; these depend on the diffusion of carbon — or carbide — in austenite. The difference exists in the carbon concentrated in the outermost layers.)

I know from my own experience that it is not a very difficult matter to get as high as 2.00% carbon in almost any grade of steel if the carburizing is conducted under certain conditions. I know of a practice at one company which is producing deeply cased shafts of S.A.E. 5130 with carbon content consistently greater than 1.7% in the outer 0.010 in.; specifications require a hardness of at least Rockwell C-68. This is done by carburizing at 1750° F. for approximately 8 hr. and then dropping the temperature to approximately 1500° F.

I have recently seen several examples where steels carburized at 1680° F. showed a carbon content approaching 2.00% at the surface. Some years ago, when using Houghton's hydrocarbonated bone black and attempting to keep under a maximum of 1.05% carbon, and where each shipment was checked several times for case concentration by turning specially designed test samples and analyzing for carbon content, we would find cases up to 1.80%. These steels were mostly plain carbon S.A.E. 1020, although a considerable portion of the work carburized was S.A.E. 5120.

Possibly the normal fluctuation of temperatures in commercial operations may cause carbon to build up at the surface. It is possible to convert thin shim stock, 0.002 in. thick, to practically pure carbide (6.7% C) by carburizing at low fluctuating temperature. Also, it is practically impossible to carburize, in mass production, without some evidence of high concentration of carbide at the extreme surface. Likewise the temperature uniformity in most furnaces leaves much to be desired. This matter of temperature fluctuation in practical furnace work is something that probably has a major influence on carbon concentration at the extreme surface.

I have seen evidence of surplus carbide even in the nickel and nickel-molybdenum steels, which have the least tendency to form high carbon cases. In these steels it is very unusual to have a carbon content much over that indicated as in equilibrium at the carburizing temperature, yet I know of one metallurgist who was carburizing nickel-molybdenum gears at two temperatures, the first of approximately 1700° F. followed by a cooling to approximately 1200° F. and then by re-carburizing at 1500° F. for 4 hr., whereby he obtained a carbon content which exceeded 1.70% in the first 0.010 in. of case.

It is to be hoped that Mr. Harris will be able to investigate the conditions that cause such high carbon surfaces. Evidently the gaseous atmosphere he is now using does not do this, to any discoverable amount. However, I believe it equally true that pack carburizing at relatively low temperatures (say 1600° F. or less) will result in thin layers of excess carbide, and the carbon analysis at the very surface will be the higher as the temperature is lower.

HARRY W. MCQUAID
Assistant Chief Metallurgist
Republic Steel Corp.

## A Versatile Non-Ferrous Etchant

PITTSBURGH, PA.

*To the Readers of* METAL PROGRESS:

It may be of interest to know that a simple etchant has been in general use for non-ferrous metallography. The etchant has the following composition:

| | |
|---|---|
| Ferric chloride | 5 gm. |
| Ethyl alcohol | 96 ml. |
| Hydrochloric acid (conc.) | 2 ml. |

The ferric chloride is first dissolved in alcohol, and then the solution is acidified by the concentrated hydrochloric.

Notwithstanding the fact that there are a number of ferric chloride etching reagents commonly in use, the writer has not seen any mention of an etchant having the foregoing formula. It has been adopted because of its optimum etching performance, and is the result of much experimentation.

In employing the reagent, specimens may be etched either by light swabbing or by immersing with gentle agitation. The time may vary from one second to over several minutes, depending on the condition and composition of the specimen. Since the alcohol tends to evaporate from the solution upon standing in open dishes, the etchant should be replenished frequently, otherwise its performance will be impaired.

Excellent results have been obtained on a number of commercial and experimental non-ferrous alloys containing aluminum, copper, lead, magnesium, manganese, nickel, tin, and zinc. In general, it develops excellent structural detail with sharp grain boundary delineations, and avoids any staining which is normally to be expected when working with most ferric chloride reagents. Moreover, the etchant is invaluable for removing with ease any flowed metal which often results from grinding and polishing operations.

Though not necessarily regarded as a standard ferrous etchant, it has been used with remarkable success in etching tempered manganese steels. For this purpose, the etchant satisfied us better than either nital, picral, sodium picrate, or Vilella's reagent. This finding seems to indicate that the reagent may be satisfactory for etching other ferrous alloys, and, therefore, its potentialities should not be overlooked whenever the conventional ferrous etchants fail.

LOUIS A. CARAPELLA
Metallurgist
Mellon Institute of Industrial Research

## Differential Hardening With High Frequency Current

PEORIA, ILL.

*To the Readers of* METAL PROGRESS:

In re-typing the manuscript of my notes on the above subject, a most regrettable insertion was made, and I have no explanation of how it ever got in there. I refer to the next to last sentence of the fourth paragraph on page 493 of the March issue, starting "Even greater hardened depths ...." This sentence does not belong there and is confusing to the most important part of the article, and I hope that those who retain their copies of *Metal Progress* will run a line through it.

F. F. VAUGHN
Asst. Chief Metallurgist
Caterpillar Tractor Co.

*Microstructure of Alloys Containing Increasing Amounts of Manganese*

28.8% Mn — 33.9% Mn — 38.7% Mn

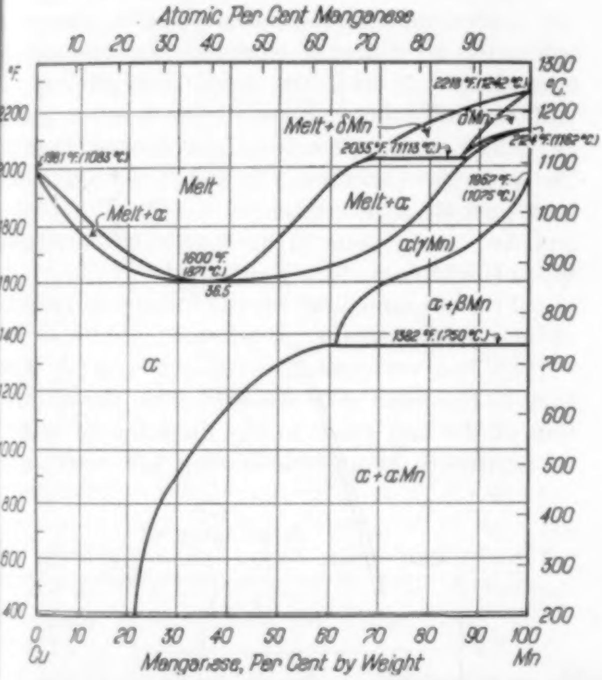
## Indoor Sport

Rolla, Mo.

*To the Readers of* Metal Progress:

The recognized copper-manganese equilibrium diagram is as shown below, reproduced from page 527 of Sachs and Van Horn's book "Practical Metallurgy". For an indoor sport, try to outline a heat treatment, based on this diagram, which will produce the structures of the six alloys shown in the strip at the bottom of these two pages. They are all substantially pure binary alloys, manganese as noted, copper balance. All are reproduced at 250 diameters; all etched with the same reagent.

*Copper-Manganese Equilibrium Diagram*




Note the beginning of a change from alpha twins at 28.8% manganese, to something at 33.9% manganese which eventually develops into a eutectoid structure at 49% manganese. The amount of this finger-print or "thumb-line" structure increases as the manganese increases.


Charles Y. Clayton
Head
Dept. of Metallurgy & Ore Dressing
Missouri School of Mines


## Armoring the President's Car

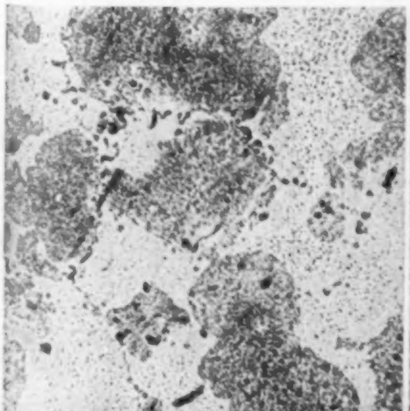
Cairo, Egypt

*To the Readers of* Metal Progress:

About four days before President Roosevelt and his staff arrived for the Cairo conference with Prime Minister Churchill and his staff, last November, a secret service man drove a Packard sedan into the Base Automotive Maintenance Shops near Cairo and asked if we could make it thoroughly bullet and bomb proof. We could have not more than four days. Three would suit him even better.

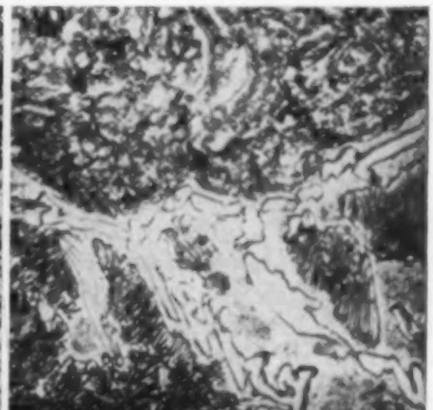
The car was of standard U. S. Army style and paint job. The outside we didn't touch a bit; it didn't need any distinguishing marks. The driver's seat we didn't touch, either. But from the partition on back we took everything out carefully, upholstery and cushions and even the window-glass, and went to work.

We had no pattern to work by, but we had a definite idea of what was wanted: Protection first. That meant shielding the cab from any chance bullet from side or top or back, or from even an explosion from the bottom. But we had to leave the windows clear. The President wanted



43.8% Mn

49.2% Mn



59.5% Mn

to see and be seen. We had to give him an armored limousine, not a black-out car.

We made our patterns out of paper first and then plywood. Then we cut armor plate to fit, and stitched it in. It was a day-and-night job. During those three days we kept our Lincoln welder running 18 hr. a day. The armor was the stuff used to protect the nose of a P-38 or P-40 from bullets. Fortunately it was not put to a ballistic test when shielding the President!

As much as possible the protection was kept concealed and the whole job was neat and inconspicuous. Except for the weight and thickness of the doors, noticeable when you climb in, you are scarcely conscious that this car had been built over. The armor plate was welded in place, which was neat enough. Then the upholstery was put back and fastened, so the back seat would again be comfortable.

A small blower was built in to keep the air circulating, because the rear window was sealed over and the front and side windows covered with tight-fitting chunks of bullet proof glass.

From the outside the windows look about the same. Inside, however, the iron brackets supporting the heavy glass — welded in place — could not readily be concealed. After all, this was a matter of military safety; not something to do with a lady's boudoir. No one complained about the looks of the job, although the President did refer to the car as "the County Jail!"

L. L. WILKINSON
Lt., Ordnance Dept., U. S. Army

## Temper Brittleness

SOMEWHERE IN FRANCE

*To the Readers of* METAL PROGRESS:

Temper brittleness, which occurs in some quenched and tempered steels when final cooling after tempering has been too slow, involves certain characteristics peculiar to quenching phenomena; the principal difference is that the effect is confined almost exclusively to the brittleness or, inversely, the steel's ductility.

It was therefore quite natural for Messrs. Jolivet and Chouteau to study the phenomenon by the same methods used so successfully to study the hardening process — namely, the isothermal decomposition of austenite at various temperatures. This brought out some new and interesting results:

For a given steel, brittleness after tempering appears to resemble the results from rapid quenching for hardening. Thus, a critical cooling velocity $V_c$ marks the change from high ductility $K_1$ to a low ductility $K_2$.

For our present purposes a steel can be characterized by two coefficients or parameters:

1. The critical cooling velocity $V_c$ for the appearance of brittleness, representing the sensitivity of the phenomenon.

2. Absolute susceptibility $S = K_1/K_2$, or relative susceptibility $\sigma = (K_1 - K_2)K_1 = 1 - 1/S$, representing the intensity of the phenomenon.

This coefficient $S$ is the only one that has formerly been considered, and it has been measured quantitatively, if at all, after holding in a temperature range of 500 to 550° C. (925 to 1025° F.) where brittleness occurs with considerable speed, clearly shown by the curves in Fig. 1.

The tempering time $T_1$ and temperature $t_1$, which often alter the value of $S$ considerably, have little influence on the critical speed $V_c$. On the other hand, different steels of the same chemical composition as regards amount of alloy but submitted to different working and fabricating operations will have the same susceptibility, $S$, and far different values of the critical speed (Fig. 2). As to quenching phenomena, that is, the possible variations in the temperature of transformation of austenite, noted as Ar′, Ar″, and Ar‴, they seem to have no relation to this type of brittleness in a given steel.

Two unpublished results, however, appear to be most important, as follows:

1. The two characteristics $S$ and $V_c$ may vary in the same steel depending on the orientation of the test piece to the direction of rolling or maximum elongation during hot work, and

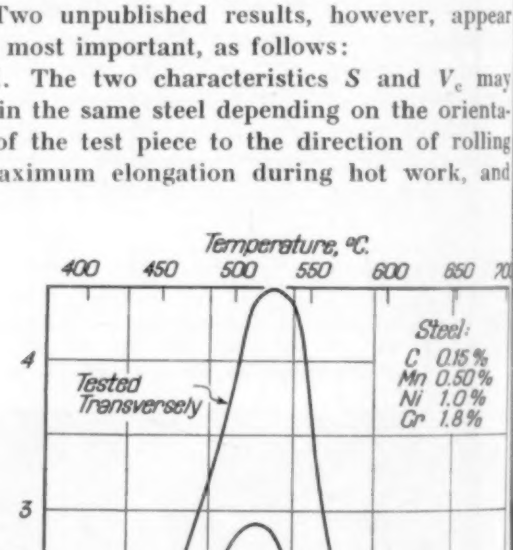



*Fig. 1 — Variability of Intensity of Temper Brittleness in a Certain Steel When Held for a Given Time at Various Temperatures*

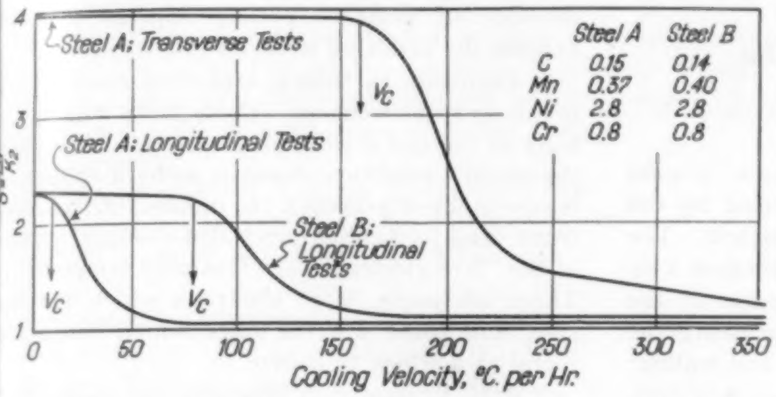



*Fig. 2 — Variability in Cooling Speeds Necessary to Suppress Temper Brittleness in Two Nickel-Chromium Steels*

can vary considerably in the transverse and longitudinal directions (Steel A in Fig. 2). Best ductility therefore requires an optimum reduction of the metal in working for the desired combination of longitudinal and transverse toughness, and thus the influence of the final treatment which can either reduce or considerably exaggerate the transverse brittleness.

2. More complete tempering by prolonging the holding time $T_1$ or raising the temperature $t_1$, which tends to coalesce the microconstituents, reduce and even entirely suppress the temper brittleness. For example, the nickel-chromium steel of Fig. 1 may have $S = 4.6$ when tempered for 15 min. at a given temperature; $S$ falls to 3.8 when the time is increased to 30 min., 2.7 at 1 hr. and approaches 1.0 when tempered 16 hr. On the other hand, if 30 min. be judged to be the maximum time permissible, $S$ may drop from 3.8 to 1.3 by increasing the temperature 70° C. (125° F.).

These results indicate that temper brittleness is the manifestation of a variable solubility in alpha iron of a constituent or phase which forms at the time of tempering, and which later separates during slow cooling or during holding at a lower temperature $t_2$. This embrittling precipitate probably accumulates in the crystalline planes of the ferrite.

If the phase formed on tempering is disperse, much of it will be in solution at the tempering temperature, with later intra-granular re-precipitation causing brittleness. If the initial phase is coalesced, there will be only a slight amount in solution around the surface of the particles, and re-precipitation will probably occur *on* the particles and will not induce brittleness.

Temper brittleness is not a phenomenon which occurs only in certain steels considered "sensitive" or "susceptible". In principle it is always present, but in certain cases the $S$ ratio is very slight, or the speed $V_c$ is beyond the experimental and practical limits, so it cannot be observed in practice. On the other hand, when it does occur it can be reduced or suppressed entirely by:

1. Decreasing the holding time in the critical range for occurrence of this brittleness with rapid subsequent cooling after tempering.

2. Coalescing the preliminary dispersion, by proper adjustment of the tempering temperature and time.

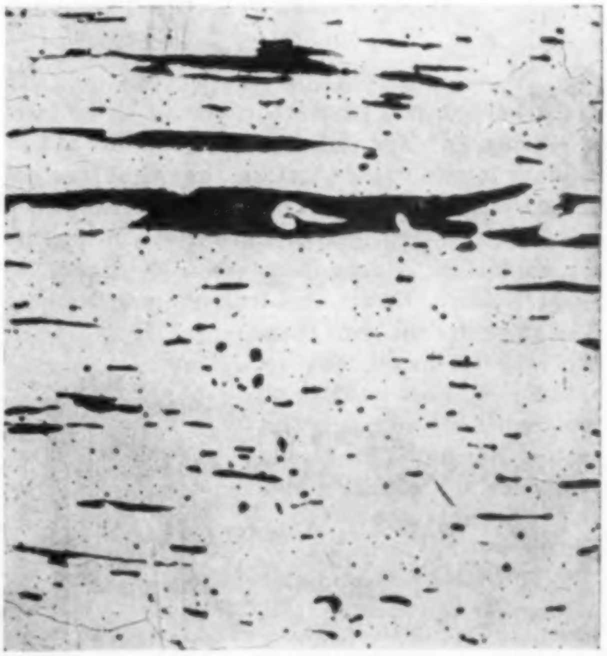
ALBERT PORTEVIN
Bessemer Medalist

## A Civil War Ghost

JAMESTOWN, N. Y.

*To the Readers of* METAL PROGRESS:

A piece of wrought iron, alleged to have been cut from the armor plate of the Confederate ram "Merrimac", was brought into our laboratory.



Inspection revealed an interrogation point in the slag. Does this really mean that the piece is not the genuine article?

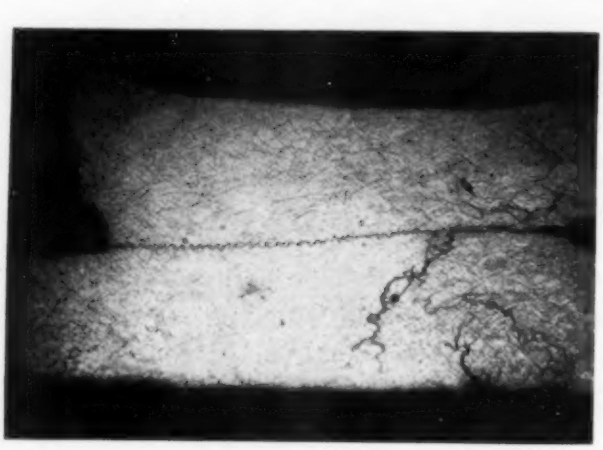
STEPHEN HUJBER, JR.
Metallographer
Marlin-Rockwell Corp.

# Brass Welds,
## Made by Detonation Impulse

BUFFALO, N. Y.

*To the Readers of* METAL PROGRESS:

The adjoining micrographs show a weld between two thin brass disks produced by the detonation impulse in the set-up sketched. The disks were of half-hard brass approximately 1 in. diameter by 0.035 in. thick. All parts in the set-up were held securely by tightening the threads of the seamless tubing at top and bottom; the detonator was the only part not securely held.



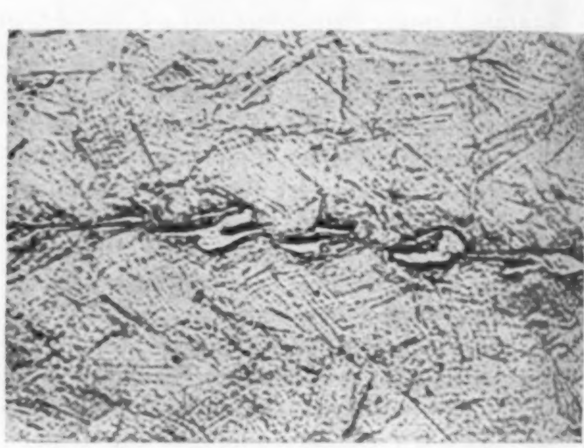


*Fig. 1 and 2 — Section Through Disks of Half-Hard Brass. Welded During Test of Explosive, at 100 and 250 Diameters Respectively*

The specimen was recovered during routine tests of explosives. The object of the test was not to produce a weld and, therefore, the metal was not prepared in any way to facilitate that result.

It would seem that the metal was heated by the explosion to a temperature high enough to cause welding. Were this true, the metal would be softer after the weld than the original metal, due to subsequent slow cooling of the half-hard sheet. The fact is the metal fragment is somewhat harder than the original — probably caused by cold working.

The opinion is held that detonation is transmitted by an extremely sudden impulse which produces a pressure increase as sudden as that produced by ultrasonic waves. (See *Journal* of the Franklin Institute for June, 1943, page 553.) Such a sudden increase and decrease of pressure perhaps can be used to explain the resulting weld, as follows:

According to theory, electrical conductivity is due to free electrons. These move within the body of the metal with little interference. When the metal's condition changes, as by a change of temperature or pressure, the number of free electrons (and its conductivity) also changes. (Some of the "free electrons" are free only temporarily. There are many more electrons which are not free, and those are the ones which cause the metal as a whole to cohere.)

Prof. Bridgman of Harvard has shown that the electrical resistance of most metals decreases when the pressure is increased. Increased pressure, then, causes a larger proportion of the electrons to exist in the free state. Now then, if two pieces of metal were held firmly together and subjected to extremely sudden pressure changes the number of free electrons would very suddenly increase and decrease. As we have seen, the coherence of the metal is due to the electrons which are not free. When the number of free electrons suddenly decreases or becomes fixed, it is conceivable that they might be in such a position as to cause adhesion between two pieces of metal as well as to remain entirely within the original metal.

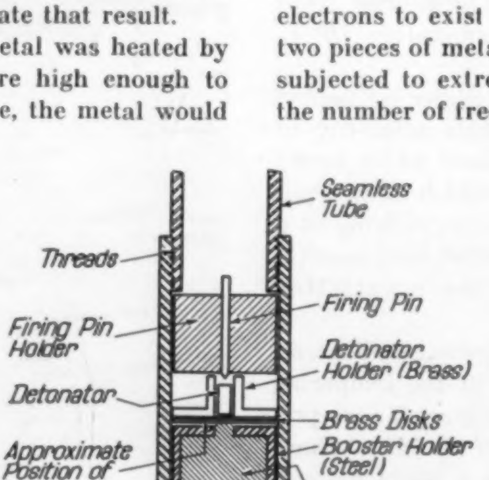



*Fig. 3 — Cross Section of Set-Up for Testing Explosive*

The photomicrograph at higher magnification shows the weld interrupted by voids or inclusions. This interrupted weld is believed

to be due to the fact that the sudden impulse caused one disk to slip over the other, and in this way the impurities on the metal surfaces were segregated and the weld occurred at the points where the surface impurities had been rubbed away.

Bergmann, in his book on "Ultrasonics and Their Scientific and Technical Applications", has discussed some of the effects of ultrasonics on metals. He says: "Hollmann and Bauch were able to show that ultrasonics produced in a nickel rod a loosening of the molecular magnets, whereby the process of reversal of magnetization is considerably facilitated. We are, therefore, dealing here with a loosening in the crystalline structure of ferromagnetic material by high frequency sound waves....

"The rate of diffusion of nitrogen into steel is very small at the temperatures commonly used. ....This depth of penetration is considerably increased, according to Mahaux and Guillet, under the action of high-frequency sound waves, and penetration also takes place more quickly."

It seems to the writer that it would be worth while to investigate metals which have been especially prepared to facilitate welding with explosive charges, and also with ultrasonic waves of known frequencies, to determine the exact conditions under which the various metals would join together.

LEROY R. CARL

## Farewell to Metallurgy

KNOXVILLE, TENN.

*To the Readers of* METAL PROGRESS:

You may be interested in a photograph of something I found on the blackboard the morning of my final class for Army Specialized Training Program students. They had recently been ordered back to combat service, and despite their general disappointment in being yanked out of engineering school, could still see the funny side of things. Latrine rumor has it that the cartoonist was Pfc. William Wei Lee.


DAVID J. MACK
Asst. Prof. of Chemical Engineering
University of Tennessee

## Order-Disorder in Micro-Photo Compounds

WORCESTER, MASS.

*To the Readers of* METAL PROGRESS:

In a recent letter published in March, Elsie L. Garvin has pointed out that the newly developed technique of studying the microstructure of metals by radiography is misnamed when it is called *microradiography*, just as it is now generally accepted by metallurgists that *microphotography* should not be used when *photomicrography* is meant. By analogy with the latter, the correct word for the new technique would be *radiomicrography*, and not *macroradiography* at all, as proposed by Miss Garvin on the erroneous assumption that low magnifications are involved. As a matter of fact, a magnification of 100 diameters is commonly used in radiomicrography so that *micro* and not *macro* is the correct word element. Furthermore, the word *macroradiography* is just as wrong from the standpoint of the order of the word elements as is *microphotography* when *photomicrography* is meant, at least if any rules are to be observed as to the manner of building up such words. It should be kept in mind that in all these cases the generic words are *micrography* and *macrography* and it is to these that the prefixes should be attached.

L. P. TARASOV
Research Laboratories
Norton Company

WATERBURY, CONN.

*To the Readers of* METAL PROGRESS:

Elsie Garvin's comment seems to have overlooked the fact that, in English at least, the terms which have been accepted through common usage may not at first glance appear the most logical for the purpose. A typical example of such illogical usage is contained in her own discussion where the word "photomicrograph" implies considerable enlargement whereas the word "macrophotograph" implies only a minor degree of enlargement. (Why not photomacrograph?)

In coining or compounding a new word it is necessary to consider the euphony of the structure as well as its logical meaning deduced from

the etymology of associated word types. Inspection of Webster's New International Dictionary (Unabridged) shows, among others, the following examples where the prefix "micro-" implies the recording, on a visible scale, of measurements made of minute quantities: Microanalysis, micromethod, micromotoscope, micronometer, microphonograph, micropolariscope. By contrast, we have the following words implying a minute record of relatively gross things: Micropantograph, microphotography. Examining associated words from another direction we find the following relationships: spectroscopy — spectrography; radioscopy — radiography; microscopy — micrography. In all of these cases the suffix "-graph" indicates a graphic reproduction or recording of the entities concerned. When photography is used as the recording method it is only in the last case that it is felt necessary to introduce the prefix "photo-" to make clear just how the record was produced.

In the case of microradiography the suggested word "macroradiography" might well be substituted in, say, investigations on spot welds where the magnification has usually been of the order of about 10 diameters or less. This would conform in meaning with the word "macrophotograph". However, for techniques involving the magnification of a radiograph by larger amounts, such as 100 diameters or more, the prefix "macro-" is no longer applicable, whereas the prefix "micro-" is quite satisfactory from the etymological standpoint.

From standard usage in applying prefixes, the word "microradiography" also indicates that the radiograph occurs first and the "micro" procedure occurs later. Any such transposition of syllables as "radiomicrograph" would not have this connotation.

In short, while one might conceive of a substitute such as "magniradiography", the present use of the word microradiography seems significantly well fitted to describe this new metallurgical technique.

S. E. Maddigan
Research Physicist
Chase Brass & Copper Co.

[Editor's Closure — Let's try — note the modest use of the word *try* — to use "photograph" and "radiograph" in the pages of *Metal Progress* to mean reproductions at ordinary degrees of enlargement or reduction, and in sentences where there is no need of distinguishing between "macro" and "micro". Let's say "micrograph" when we intend to convey the idea that the object is magnified considerably in reproduction (and for this word, "micro" will be an acceptable slang replacement, at least in *Metal Progress*). If it is necessary to distinguish the method of registry we can say "photomicrograph" or "radiomicrograph". Finally let's use the words "photomacrograph" and "radiomacrograph" sparingly, when we must denote intermediate enlargements.]

*Welded, All-Metal Life Raft, Built by Weber Show Case Co. of Los Angeles for Maritime Commission. Its compartments are filled with a half-ton of supplies for 20 men, ranging from tarpaulin, flares and oars to medicine and fishing tackle. Some life-saving problems still await solution, however, such as: 1. Means for removing salt from sea water by ionic exchange; 2. Life vest that automatically inflates and turns unconscious man right side up; 3. Methods of inflating rubber boats quickly with $CO_2$ at sub-zero temperature*

# Bits and Pieces

Metallurgicus's

Own Page

## Emergency Tempering Equipment

AN EMERGENCY in our tool department, caused by a shortage in tempering equipment and a demand that the tools be given an extra long tempering cycle, was met by two dodges, each of which proved to be successful in results.

1. The tools were brought to the desired temperature for tempering in the usual manner and left in the furnace as long as the production schedule would allow. Since the permissible time was short of the desired time by some hour or hour and a half, the tools were then carefully packed in powdered asbestos which allowed the tools to cool slowly to room temperature. The machine shop reported no change in performance of these tools over tools given the long draw.

2. A discarded electric stove was set up in the hardening department. The oven regulator was checked for correct registration and a fan installed for circulating the air. This "furnace" also worked out very successfully as a tempering medium. (PHILIP F. ATWOOD, East Orange, N. J.)

## Soft Soldering on Zinc Plated Parts

JOINING of zinc plated parts by soft soldering is difficult with ordinary fluxes. Because of the "greasy" nature of the zinc, solutions of fluxing salts usually do not cling. A small amount of a suitable wetting agent, added to the flux solution, causes this liquid to remain where it comes in contact with the plating. We have found that "Tergitol" supplied by Carbide and Carbon Chemicals Corp. or "sulphatate" supplied by the Glyco Products Co. is satisfactory.

Another important requirement for good soldering is to cause the moisture to evaporate and the flux to melt on the work in advance of the flowing solder. Zinc chloride melts at 482° F., whereas solder begins to melt at 361° F. It is, therefore, desirable to use a flux having a lower melting point than that of zinc chloride, such as a eutectic mixture of zinc chloride and ammonium chloride, which melts at about 375° F. For this reason a flux solution containing 355 g. of zinc chloride, 145 g. of ammonium chloride, and 5 ml. of "Tergitol 08" in 1000 ml. of water is excellent for soldering on zinc. This flux may be applied by dipping or brushing. If any flux remains on the parts after soldering, it readily washes off in water.

When open flames are used for heating the parts to be soldered, care must be taken not to destroy the zinc coating, which melts at 787° F. A handy method for checking the temperature of the work is to use "Tempilsticks" supplied by the Tempil Corp. (H. L. CAMPBELL, Chief Metallurgist, McInerney Spring & Wire Co.)

## Rotate During Electro-Polishing

ELECTRO-POLISHING of aluminum and copper micro-specimens has proven very successful when the specimen is rotated and the following technique used:

**Aluminum** — For aluminum the usual electrolyte is employed, two parts of 60% perchloric acid added *very carefully* to seven parts of acetic anhydride. A portion of this master solution is taken for use, about 5% water being added. During the life of a batch of electrolyte it is important to avoid diluting it further, as by using wet beakers. A cylindrical glass dish 4 in. in diameter is filled with the working solution to a depth of 1¼ in., and aluminum strip on the bottom of the dish serves as a cathode. (A satisfactory area is 5 sq.in. of 0.03-in. gage.) An ice bath is used to keep the solution cold during the operation. The specimen, a ¾-in. cylinder about ½ in. long, is suspended by a clamp above the surface of the

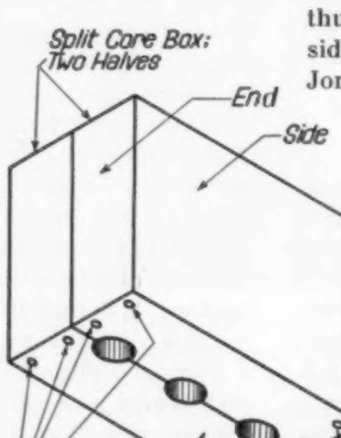
bath, only the face to be polished being submerged. Previously the specimen has been polished through 3/0 metallographic paper, and then on the first broadcloth lap using alumina. The clamp holding the specimen is attached to the bent shaft of an air-motor; thus during rotation the specimen is caused to describe small circles in the surface of the electrolyte. In order to prevent the formation of ridges on the polished surface the rod holding the specimen is turned 90° about its axis every 30 sec. Polishing for 5 min. at 50 to 70 volts and 1.5 amperes produces an excellent polish.

**Copper** — The electrolyte for copper is 85% orthophosphoric acid diluted with one part of water. The distance from the specimen to the copper cathode is about ½ in., but otherwise the mechanical details are the same as for aluminum. Using a ½-in. square specimen a polishing time of 1 or 2 min. at 2.5 volts and 0.5 ampere produces a satisfactory surface. (Albert Guy, Instructor in Metallurgy, Carnegie Institute of Technology)

## Armored Nibs on Core Boxes

An Ohio foundry has solved a maintenance problem in its core room by using fish-line guide rings of cemented carbide — quite a popular peacetime application of a material that withstands perfectly the cutting action of fast-running silk or wire fish-line. The core boxes, of aluminum, are open top and bottom, are split and the halves are lined-up with dowel pins. In use, the box is filled with rammed sand, and the box is rubbed over the bench top to smooth off the bottom.

This rubbing over the bench top covered with highly abrasive core sand wore away the bottom of the boxes unevenly, and put such a strain on the dowel pins that in time the box had to be scrapped or overhauled, the life of the average aluminum core box being only about 1500 cores. Eight of the small carbide rings let into the bottom of each box, as shown in the sketch, cured the trouble, lengthening the service life of the core box at least six-fold. (S. H. Horn, Sales Engineer, Carboloy Co., Inc.)




## Preventing Scale From Affecting Hardenability Tests

Various methods are used to protect the end and sides of the Jominy bar from scaling during heating before the quench, such as *(a)* a furnace with neutral atmosphere, *(b)* standing up in a deep layer of cast iron chips, *(c)* standing in holes drilled in a block of steel or cast iron, *(d)* standing in a closely fitting stainless steel cup, *(e)* copper electroplating.

We believe the latter is most effective, for it prevents carburization, decarburization and oxidation. A simple substitute seems to combine the advantages of copper plating with ease of application. This method consists of dipping the specimen, for about an inch of the water-cooled end, into a solution of blue vitriol (cupric sulphate 500 g., sulphuric acid 120 ml., water 3000 ml.).

The specimen must first be cleaned in 10% sodium hydroxide or some similar alkali bath before dipping, to make sure that it is clean, and free from all oil or grease. It is then dipped into the copper solution for about 30 sec., removed, washed, and again placed in the solution, and allowed to remain there for about 2 min. This results in a more permanent type of coating than is obtained from a single dip. The thickness of the copper coating depends upon the length of time that the specimen remains in the solution, but heavy coatings of copper tend to crack and chip off the specimen too easily.

This thin layer of copper does not entirely eliminate the formation of scale, but it does make a type of scale which is brittle, and does not tend to adhere to the steel. In many cases the scale chips from the specimen as soon as the column of water strikes the water quenched end, and thus there is no chance for water to creep up the sides of the bar. (R. G. Townsend, Chief Chemist, Jones & Lamson Machine Co.)

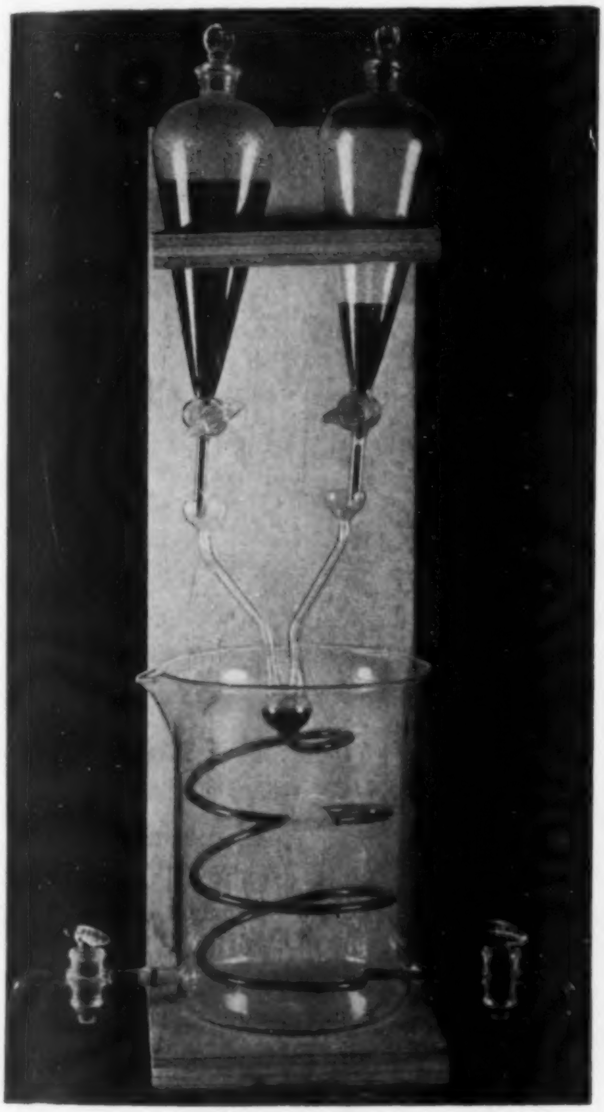
## Mixing Electrolytic Polishing Solution

In polishing electrolytically one of the chief solutions used as an electrolyte is a mixture of perchloric acid, acetic anhydride, and water. However, this has the disadvantage of being difficult to mix since the reaction is exothermic and the solution must be under 85° F.

The accompanying picture shows an apparatus designed at the Naval Research Laboratory for mixing it with

greater safety and less time, the idea being that it is safer and quicker to bring the components together in their proper ratio than to drip the acetic anhydride into the perchloric acid.

The flow of the solution is adjusted at the required ratio of 4¼ to 1 by stop-cocks on the 250 ml. separatory funnels. The two components



are mixed in the small spherical shaped reaction chamber and the cooling coil, both of which are kept cool by crushed ice. The solution is run into a container which is also kept cool by crushed ice. It is interesting to note that the temperature of the solution as it leaves the cooling coil is only 40° F. The small amount of water in the solution is added to the second container by a burette. The melted ice is tapped from the beaker by a stop-cock.

In order to construct the apparatus as shown, considerable skill is required. If a glass technician is not available, a similar apparatus could be made along the same principle from spare glass or metal parts. However, the one fact that one must bear in mind is that the solution may not come in contact with any organic material.

It has been found that this apparatus has accomplished the dual purpose of being safer and reducing the mixing time from eight hours to two hours. (JACK H. GOODYEAR, Naval Research Laboratory)

## Testing Continuity of Chromium Flash

SOME of our manufacturing operations require a chromium flash or thin plate over flat steel parts, and we have developed the following satisfactory test for continuity. The tested part must be replated; likewise only one test can be made on it, as the plate may be only 0.0005 to 0.00075 in. thick.

A simple electrograph may be used consisting of:

*(a)* Four No. 6 dry cells.

*(b)* Two small battery clips.

*(c)* One flat piece of carbon or graphite having sufficient area to accommodate the surface of specimen.

*(d)* Insulated flexible wire for making connections.

Connect the four dry cells in series and fix suitable lengths of insulated wire to the positive and negative terminals. Attach the battery clips on the ends of each lead. The flat piece of carbon or graphite is made the negative electrode and the test specimen the positive electrode. Completion of the circuit is accomplished by moistened filter paper placed between the carbon and the test specimen.

Procedure is as follows: Immerse a filter paper of sufficient size to cover the area being tested into a solution of 5 g. potassium thiocyanate in 10 ml. distilled water. Remove immediately and allow to dry for 3 to 5 min. Insert filter paper between specimen and carbon or graphite surface and contact the specimen momentarily (approximately 1 sec.) with the paper. Remove the paper and observe. If a continuous chromium flash or plate is present no color will develop. If the flash or plate is irregular, a red coloration will appear wherever bare steel is exposed, and if no chromium plate is present a deep red color will be developed over the entire surface of the paper contacted by the part. It is very important that only a momentary contact be made when checking a chromium flash. (C. H. ANESHANSLEY, Materials Laboratory, National Cash Register Co.)

## Macroscopic Etch for Weld Sections

A SIMPLIFIED METHOD of etching weld sections in carbon and low alloy steel, prior to macroscopic examination, consists of immersing the specimen for 30 to 60 sec. in a solution of 0.5 to 1% nitric acid in water. The etching time increases as the strength of the solution decreases, and this may be varied as the operator desires.

Methods commonly used for this type of etching are:

1. Swabbing with a saturated solution of ammonium persulphate for a few seconds.
2. Swabbing with 2 to 5% nital solution.
3. Immersing in 2 to 5% nital solution.

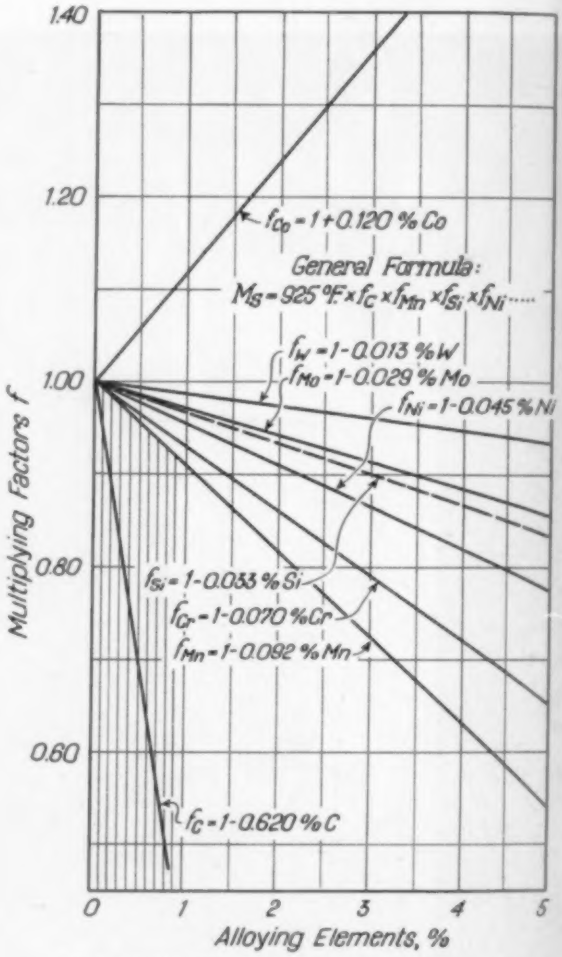
The advantages of the new method are:

1. The etched surface is not stained by pieces of cotton or lint which tend to catch when swab etching.
2. Greater uniformity and better control are obtainable during the longer etching period.
3. Surfaces on several different planes may be etched simultaneously without the possibility of staining.
4. The ingredients of this etch — water and nitric acid — are easily obtainable and inexpensive. Even tap water can be used.

The specimen is prepared by grinding on 80 and 240 grit emery belts. The surfaces to be etched are cleaned with soap and water, dried, and wiped with a clean rag soaked with alcohol or carbon tetrachloride. (It is essential that the surfaces be free from grease and dirt to obtain a uniform etch.) The etchant is mixed in any acid resistant container of suitable size; a glass beaker allows the observation of almost all surfaces as they are etching. Upon removal from the etchant, the specimen is plunged into a container into which a continuous supply of hot water is running. After thoroughly rinsing, it is dried by an air blast. (PHILIP R. SPERRY, Metallurgist, Glenn L. Martin Co.)

## Computing A″ or Ms (Transformation Temperature on Quenching) From Analysis

THE ATTACHED GRAPH will be useful in computing the temperature where martensite starts to form in a rapidly cooled piece of steel. This temperature is noted as the A″ point in the older writings on delayed transformation; Shepherd in recent articles about "martempering" dubs it the Ms point. Greninger, Chiswik, Payson and Savage have shown how the various elements influence it, and their data are plotted as judiciously as possible in the graph. The method was first submitted as a discussion to the Payson and Savage paper in ⊕ *Transactions* for 1944, page 277, but unfortunately the diagram was in error. Those who save *Transactions* rather than *Metal*



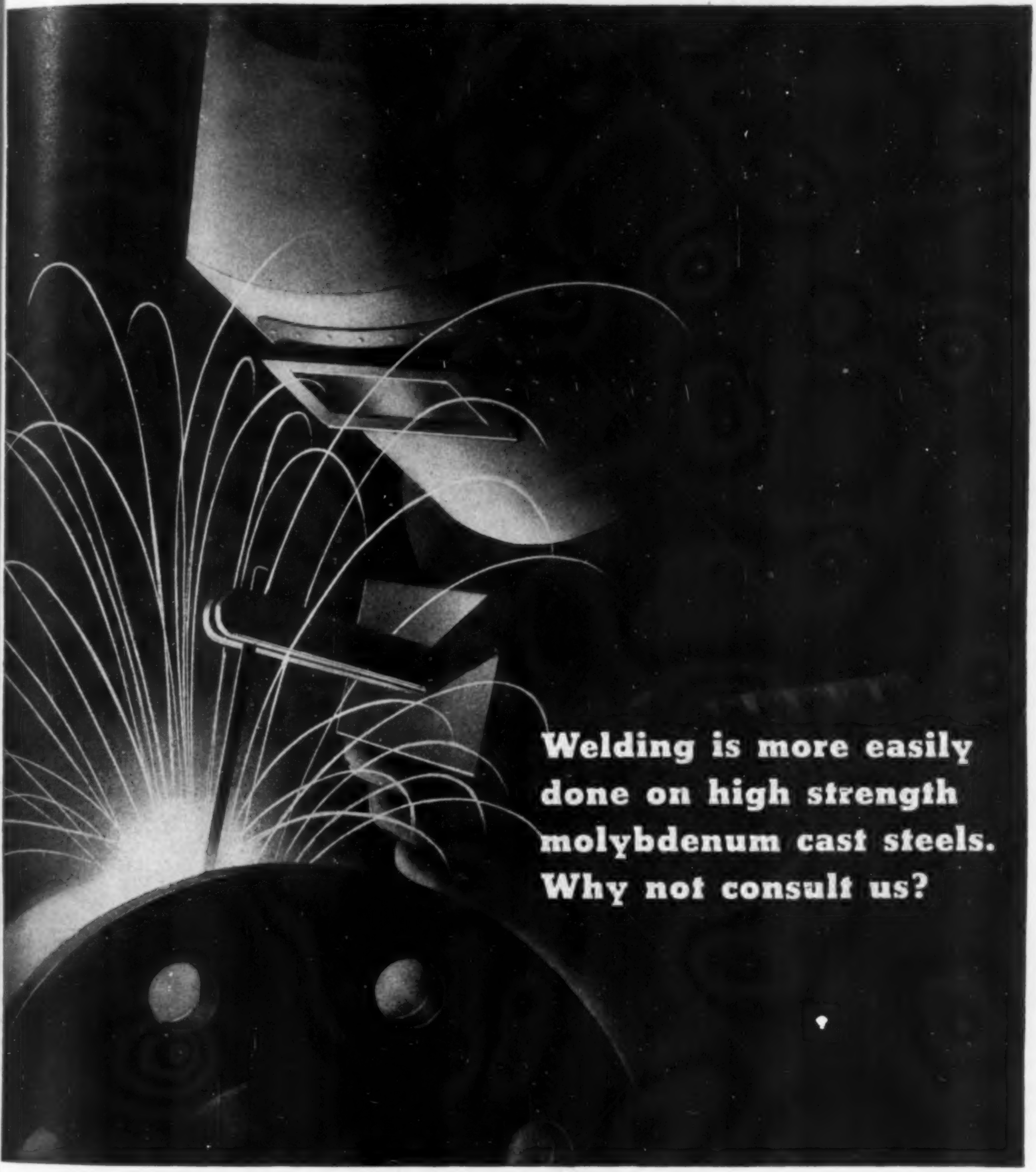

***Multiplying Factors and General Formula for Calculating Ms or A″ Point of Steel***

*Progress* may wish to cut this out and paste it over the incorrect one.

We have found the curves useful in our work. The Ms temperature can be computed, or the various factors scaled from the graph. An example follows:

| ELEMENT | % | f |
|---|---|---|
| C | 0.61 | 0.622 |
| Mn | 0.50 | 0.954 |
| Si | 0.24 | 0.992 |
| Ni | 0.16 | 0.993 |
| Cr | 0.94 | 0.934 |
| Mo | 0.33 | 0.990 |

Calculated value comes out to 500° F., which checks the observed value. (LOUIS A. CARAPELLA, Industrial Fellow, Mellon Institute of Industrial Research)


Welding is more easily
done on high strength
molybdenum cast steels.
Why not consult us?

## Personals

J. Edward Donnellan has resigned his 20-year post with the ⊕ to become vice-president in charge of sales for General Alloys Co., the organization of our good friend, Harry Harris. He will move to Boston, which does not displease Ed and Edith, both Yankees. He will leave behind a gaping hole in the Society's organization that will be most difficult to fill. His work in Cleveland is marked with a lasting monument, for the ⊕ Metals Handbook under his fostering care has grown from a few Lefax sheets into an encyclopaedic reference book of international authority. They take with them our affectionate good wishes. E. E. T.

Honored by the American Foundrymen's Association: Rufus F. Harrington ⊕, foundry superintendent, Hunt-Spiller Mfg. Co., awarded the John A. Penton Gold Medal for outstanding pioneering work in foundry sand control; Stanley W. Brinson, master molder, Norfolk Navy Yard, presented an honorary life membership in the Association; Carl F. Joseph ⊕, research metallurgist, Saginaw Malleable Iron Division, General Motors Corp., the William H. McFadden Gold Medal for outstanding metallurgical and shop practice contributions to the foundry industry, especially the malleable iron section.

Cited by the Office of the Chief of Ordnance for outstanding personal achievements in producing steel cartridge cases: Fred M. Arnold ⊕, Harry F. Ehrich and John A. Kingston of the Norris Stamping and Mfg. Co., Los Angeles, and Harlan A. Messner ⊕ of the Ohio Crankshaft Co., Cleveland.

Otto W. Winter ⊕ has been appointed vice-president of the Acme Pattern and Machine Co. of Buffalo, N. Y.

Robert S. Westwater ⊕ has resigned as metallurgical engineer with North American Aviation of Kansas to join the Naval Reserve, and is attending the Naval Academy at Annapolis.

J. C. Schonhardt ⊕, formerly metallurgist, Curtiss-Wright Corp., Louisville Plant, is now district manager for Jessop Steel Co. in the St. Louis office.

Emanuel Gordon ⊕, formerly metallurgist for Carnegie-Illinois Steel Corp., McKeesport, Pa., is now employed as metallurgist at Massachusetts Institute of Technology.

John W. Wiley, Sr., is now employed at the Nutmeg Heat Treating Co., Bridgeport, Conn.

George L. Tuer, Jr. ⊕, formerly with Aluminum Co. of America Research Laboratory, New Kensington, Pa., has joined the U. S. Navy and is stationed at Great Lakes, Ill., assigned to the Radar Division.

H. J. Elmendorf ⊕, formerly research engineer in Cleveland for American Steel & Wire Co., has been transferred to the company's plant in Worcester as metallurgical spring engineer.

# Personals

COMDR. H. O. DAHLKE has reported for duty at Charleston Navy Yard as machinery and repair superintendent.

H. C. MILLER has resigned as vice-president, Springfield Heat Treating Corp., to become plant metallurgist for the American Bosch Corp., Springfield, Mass.

COL. G. F. JENKS, U. S. Army retired, formerly associated with Taylor-Winfield Corp., has accepted a position with North American Aviation, Inglewood, Calif., in the office of quality control.

PAUL T. KEEBLER has been appointed plant manager of the industrial car division of the Phillips Mine and Mill Supply Co., Pittsburgh, succeeding R. R. PHILLIPS, who recently joined the Armed Forces as lieutenant (j. g.) in the U. S. Navy.

Promoted from major to lieutenant colonel: PAUL C. CUNNICK, chairman Tri-City Chapter, in charge of metallurgical laboratories, Rock Island Arsenal.

DONALD E. RODA, formerly with the Rochester Products Division of General Motors Corp., Rochester, N. Y., is now chief metallurgist and head of the process engineering department, Pacific Division, Bendix Aviation Corp., North Hollywood, Calif.

ROBERT B. SOSMAN and JAMES B. AUSTIN have been appointed assistant directors of U. S. Steel Corp. Research Laboratories, Kearny, N. J. ROBERT H. ABORN has been appointed supervisor of physical metallurgy.

HARRY D. CHURCHILL, associate professor of mechanics, Case School of Applied Science, Cleveland, has been promoted to full professor.

N. B. LANTZ, formerly industrial gas engineer with the Public Service Co. of Indiana, has been appointed manager, standard equipment division, Dempsey Industrial Furnace Corp., Springfield, Mass.

DONALD B. WILLIAMS, formerly metallurgist at the Duquesne Works of Carnegie-Illinois Steel Corp., has been appointed assistant chief metallurgist, Duquesne Smelting Corp., Pittsburgh.

W. E. REMMERS, past chairman, Chicago Chapter, has been elected vice-president of Electro Metallurgical Sales Corp., New York.

L. F. GRAVES has been promoted from heat treat and X-ray foreman at LaPorte Works, Allis Chalmers Mfg. Co., to works metallurgist.

A. E. RHOADS, formerly manager of the Detroit Electric Furnace Division of Kuhlman Electric Co., has been elected executive vice-president and general manager of the Kuhlman Electric Co., Bay City, Mich.

CLINTON E. SWIFT, formerly manager of the welding division of Ampco Metal, Inc., is now assistant manager of the engineering and research department of Eutectic Welding Alloys Co.

# Personals

Albert R. Fairchild ⊕, formerly in charge of the heat treatment department at New York Shipbuilding Corp., is now metallurgist with the Troy Heat Treating Co., Troy, N. Y.

O. L. Preble, Jr. ⊕ is now resident field engineer in the New York metropolitan area for Philco Corp.

Jerold L. Welch ⊕, formerly with Fedder Mfg. Co., Buffalo, N. Y. as chief inspector, and Sterling Engine Co., Buffalo, as manager of Syracuse Subcontract Office, is now products engineer for Superior Foundry Co., Cleveland.

James H. Nangle ⊕, formerly with Pratt & Whitney Division, United Aircraft, East Hartford, Conn., is now metallurgical consultant, Foster Dee Snell, consulting chemists and engineers, Brooklyn, New York.



Elected to the board of trustees of Battelle Memorial Institute, Columbus, Ohio: Zay Jeffries, past president ⊕, technical director, lamp department, General Electric Co., Cleveland, chairman of Carboloy Co., Inc., and vice-chairman of the War Metallurgy Committee.

M. D. Bensley ⊕, formerly assistant to the president, Shenango Penn Mold Co., has been appointed general manager of the three plants of H. K. Porter Co., Inc., Pittsburgh —namely, Mt. Vernon Car Mfg. Co., Wheel Foundry Division of Mt. Vernon Car, and J. P. Devine Mfg. Co.

Floyd J. De Van ⊕ and Henry A. Bischoff have formed the Hy-Alloy Steel Co., Chicago, to carry on the distribution of alloy steel bars from mill and warehouse stocks.

F. L. MacNamara ⊕, formerly superintendent, zinc division, Ball Bros. Co., Muncie Ind., is now manager, can division, Ray-O-Vac Co., Fond du Lac, Wis.

E. Qvarnstrom ⊕ is now heat treating engineer with the tool engineering department of Grumman Aircraft Engineering Corp., Bethpage, Long Island, N. Y.

John F. Crum, Jr. ⊕ has resigned as plant metallurgist of plant No. 3, Bohn Aluminum and Brass Corp., to enter the Navy in the near future.

W. A. Dye ⊕, formerly melting superintendent at Copperweld Steel Corp., is now in the melting department of the Universal-Cyclops Steel Co., Bridgeville, Pa.

Promoted by Standard Steel Works Division of Baldwin Locomotive Works: John D. Tyson ⊕ from manager of sales and metallurgy to divisional vice-president.

David F. Carter ⊕, formerly metallurgist at Firestone Tire & Rubber Co. of Tennessee, is now a metallurgist for Republic Steel Corp. in Chicago.

Alex Rubin ⊕ is now assistant metallurgist at the Norfolk Navy Yard.

William A. Whiteside has been elected secretary of the Quaker Chemical Products Corp. of Conshohocken, Pa.

## Inspection in a Manufacturing Plant*

By D. B. Keeling and L. E. Cisne

THE "Average Outgoing Quality Limit" double sampling plan involves the examination, on a "go no-go" basis, of a specified number of articles taken at random from a large group. The acceptance or rejection of this entire group is usually made on the basis of results obtained from the first sample alone. However, if the results from the first sample are not conclusive, an additional sample is examined. Just how large the sample lot should be is shown in statistically determined tables of lot sizes and corresponding sample sizes. Double sampling may be applied to the output of any unit operation capable of sufficient uniformity.

### Analysis of Process

To determine the applicability of this plan it is necessary to examine the manufacturing and inspection processes and all data available regarding past quality performance, such as records of per cent defective, consumers' complaints, and so on.

The *lot* of articles to be examined should consist of product which is available in its entirety for acceptance or rejection at one time. For sampling purposes, the lot should consist of articles made from uniform raw material by operators of equivalent skill and by machines or methods of equivalent precision.

Lots should be as large as the limitation of uniformity will allow. In sampling from larger lots it becomes increasingly important that each sample should be a group of articles *taken at random* from different locations throughout the lot so that it will represent an impartial cross-section.

There must, of course, be a known standard of acceptability for the individual article.

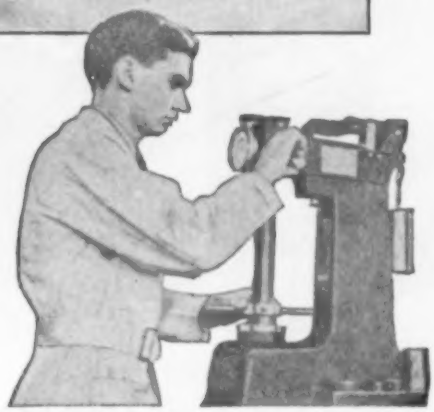
Close cooperation between production and inspection personnel is required in assuring that rejected lots are thoroughly cleared of all defectives.

### Double Sampling Table

Tables are constructed by the director for a variety of "Average Outgoing Quality Limit" (AOQL) values and "Process Average" (PA) classes. The AOQL value is the maximum value of average per cent defective in the product after inspection, (Cont. on p. 118)

*Abstracted from *The Bell System Technical Journal*, June 1942, page 37.

*The Most Important Thing*
*To Look for*
*in Resistance Welding Electrodes*
*is Something You Cannot See . . .*



# Quality Control . . . for the Right Alloy, Correctly Produced

Prescribing the proper electrode alloy for a specific welding job is important. Even more important is the ability to make that alloy so that its composition never varies in process of production.

Here at Mallory we have mastered the art. We know how metallurgical processes affect our alloys. We know what physical and electrical properties they impart. And we duplicate them again and again through a rigid system of quality control.

This thorough and scientific regulation starts with the raw materials. It continues through every detail of operation to the finished tip, roll or die. It follows the finished product into your plant, checking on performance in actual operation. It includes hundreds of sample melts in experimental furnaces, Rockwell tests for hardness, microscopic examinations for grain size, repeated alternating stresses in fatigue machines, elastic limit determination, exact measurements of tensile strength, electrical and thermal conductivity.

With such attention to detail, it is possible for you to establish high speed set-ups and procedure which, once fixed upon, require little if any change. Write today for specific data.

***Make Your Dollars Fight —Buy More War Bonds***

**P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA**

**P. R. MALLORY & CO. Inc**
**MALLORY** *Standardized Resistance Welding Electrodes*

## Inspection in Manufacturing

*(Continued from page 116)*

which the sampling plan will assure over a long period of time. The process average (PA) is the normal per cent defective which is to be expected from the process.

To determine what AOQL value should be adopted, it is necessary to decide upon a maximum average per cent defective which may be permitted without serious consequences to the product user.

**Inspection Layout** — After the AOQL value has been established, definite instructions in the form of a "sampling layout" should be provided for the inspector's use. He should record the results of his inspection at the time of his observation. These records should be summarized periodically, and the process average (PA) should be computed at least once every six months.

**Control Chart** — The per cent defective is plotted and control limit lines are drawn around the process average to indicate the variation that may be expected due to random sampling. These control limits are determined by the following formulas:

Upper control limit for fraction defective

$$= p + 2\sqrt{\frac{p(1-p)}{n}}$$

Lower control limit for fraction defective

$$= p - 2\sqrt{\frac{p(1-p)}{n}}$$

where $p$ = process average fraction defective
$n$ = average number of articles in first samples inspected during the summary period.

Rejected material should be repaired and returned for reinspection as one lot.

**Changes in AOQL and PA** — There is no assurance that the value originally selected for an AOQL will continue to be the most satisfactory in view of changing factors relating to the product.

If the process average has been reduced, an attempt should be made to make the change permanent, or if it has been increased, the cause should be eliminated.

**Interpretation** — As long as the plotted points of the per cent defective remain within control limits, the fluctuations are no greater than may reasonably be expected from a uniform manufacturing process. However, if a point goes above the upper control limit, the cause may be defective workmanship, defective raw materials, or even a change in the severity of inspection. If a point goes below the lower control limit, the cause may be an improvement in quality or a change in the definition of a defect through misinterpretation or changes in inspection equipment or method of check. To achieve control of the quality of a product, direct and immediate action must be taken in order to stem unfavorable trends.

## Welded Armored Vehicles*

THE INCREASING TEMPO of mechanization in this war has emphasized the urgent need for vastly increased output of armored fighting vehicles. In the forefront of this general advance has been the increased use of electric arc welding, particularly for the hulls and turrets of armored fighting vehicles, including tanks. At the same time, an important extension in the application of welding has included its use in field repairs. Battle experience in Libya and the Middle East has shown that welding of damaged hulls of both tanks and armored cars can be carried out more effectively than repairs by any other process. A study of the effect of shell fire on welded joints has proved that they can take tremendous punishment and retain a large measure of fighting efficiency.

In the early types of tanks considerable danger to the crew arose from flying bolt and rivet heads, which became lethal weapons under attack by projectiles of heavy caliber, even where the armor itself was not defeated nor the tank put out of action. This hazard has been surmounted, but by uneconomical methods, involving use of studs, screwed bolts, drilled and tapped holes in armor plate, operations causing high consumption of expensive drills and taps. The necessity for all joints to be immune to bullet splash is a further complication of design.

The alternative from a production standpoint is to profile all plate by machine gas cutting and to fabricate by arc welding, provided no reduction in immunity and serviceability is introduced thereby. Far from this being the case, there is now ample evidence to prove that the welded tank is superior in withstanding punishment under attack in battle and, at the same time, its inherent structural rigidity is an important factor in reducing mechanical wear and breakdown. At the same time, complete water-tightness for fording in shallow waters and over marshy ground can be guaranteed.

Every scout, reconnaissance, and armored car produced in Great Britain since the outbreak of war has been provided with welded hulls and turrets. As there are many thousands of these vehicles in service, welding procedure has been thoroughly established on sound lines.

Fabricated work of this type is greatly facilitated by well-designed jigs and manipulators, in which the hull can be turned for down-hand welding of the joints. Plate sub-assemblies are welded in jigs so designed as to give controlled restraint to the plates, after which the welded sub-assemblies are put into the main jig and manipulated for final welding in the down-hand position.

*Abstract of article in *The Engineer*, June 18, 1943, page 485.

Rapid plate edge preparation prior to welding has been greatly accelerated by the extensive use of flame machining, a process combining accuracy with speed.

Progress in the welding of armor for medium and heavy tanks has been somewhat slower, not because there have been official doubts as to the reliability of welds, but because *production* must be the ruling policy.

Actual construction of the hull and turret has never proved to be a bottleneck. A change-over to welding on production lines already fully planned, tooled, and operating in the manufacture of bolted or riveted tanks could not but entail a major industrial operation, resulting in a significant though temporary drop in output.

Nevertheless, it has now been established policy for some time that new designs for all types of armored fighting vehicles, regardless of their size, shall be based from their inception on welded construction.

A special branch has been appointed within the Department of Tank Design to deal with this aspect of construction, responsible for advising on and approving designs and production procedures to insure reliability and consistency in quality, and for coordinating investigational activities.

A considerable amount of research has been conducted by Government and industrial laboratories in connection with the welding and gas cutting of armor plate during the past decade. A wealth of information has been built up on the behavior of various types of welded constructions under different forms of attack, and a vast fund of experience gained in developing the most efficient manufacturing procedures and equipment.

Many problems have also been faced in the development of suitable electrodes and welding techniques and in the improvement of armor steels with regard to their weldability.

## Extrusion of Airplane Parts*

By Phil Koenig

A PROCESS often called "impact extrusion" has been used to form articles like collapsible tubes for toothpaste from soft alloys. A single stroke of a press changes a slug of metal into the completed article. Similar methods are being used to form some small parts for airframes, rapidly and extremely economically, replacing castings, forgings, or machinings from solid stock.

"Impact" is hardly necessary, as small parts can be produced in conventional crank presses available in almost every shop. *Speed* is not necessary, except to give large numbers in a short time. *Pressure* is the prime necessity — unalloyed aluminum requires about 90,000 psi. pressure, while 24S alloy needs twice as much. Dies must be strong enough to withstand these pressures; working parts of dies and punches may be chromium plated to resist wear, and strongly supported and surrounded by die rings or plates. Minimum clearances are necessary to reduce flash. Once the correct dies are properly placed, dimensional tolerances are automatically insured.

There are no set limitations in regard to the form or shape of the parts. Symmetrical and cylindrical shapes might be best suited for production as far as the tools are concerned. Square, rectangular and oval, as well as unsymmetrical shapes, can be produced with equal ease after the tools have been made. There is no limit to the height which a slug can be driven. The stroke of the press might control this but the metal will flow to any extreme if the required force is applied to the tools.

Frequently it is handier to drill or punch a hole in an extrusion than to build the complicated die and stripper required to complete the piece in a single stroke press.

An example is a roller on the ammunition feed. It starts as a disk cut from a 1½-in. round aluminum alloy in soft condition, cut accurately to size from a bar in an automatic screw machine. The diameter of the (Cont. on p. 126)

*From "Impact Extrusion and Cold Pressing of Airplane Parts", *S.A.E. Journal (Transactions)*, November 1943, page 415.

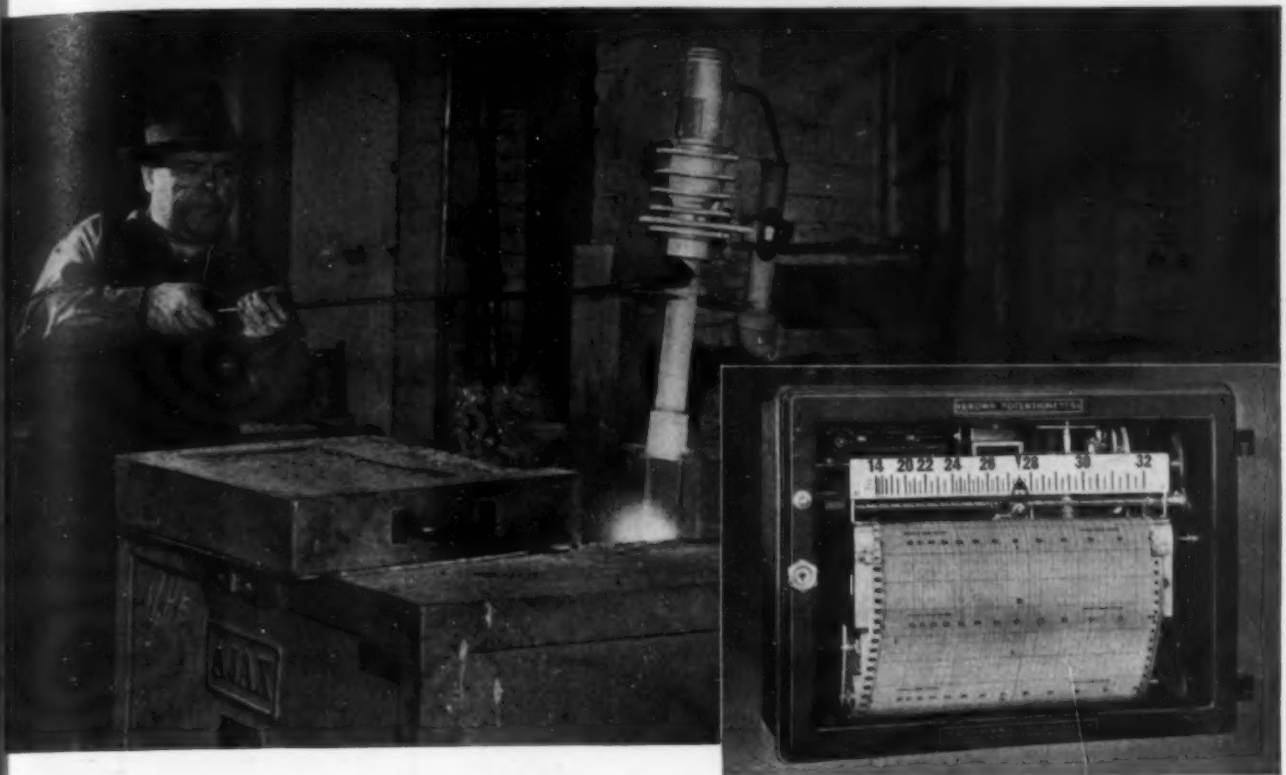
## Extrusions

*(Cont. from p. 124)* finished part is slightly more than 1½ in. so the disk slips into the die easily. When the plunger comes down the disk is pressed over a ¾-in. form punch in the bottom of the die, thus putting a deep dimple in the base. Metal is forced up in an annular slot around the sides of the punch, and the result is a cup shaped a good deal like an oversized percussion cap, about 1½ in. in diameter, and 1½ in. high. The 0.9024 (+0.001, −0.000) dimension, inside diameter of cup walls, is held much closer than would be possible on a turret lathe. About 45% of the material required for machining this part from a bar is saved, and 20% of the time. Such parts, of course, can be heat treated for strength requirements after being formed from annealed alloy.

## Sigma Phase in Pure Cr-Fe Alloys

LACK OF DUCTILITY in the commercial chromium-iron alloys (stainless irons) containing upwards of 16% chromium has led to the "explanation" that they must contain a brittle constituent of some sort. In fact, this suppositious phase was used to explain the embrittlement of the 5% chromium steel tubing, when tested cold after long heating in a petroleum still. No claim was made that this phase could be seen in the microstructure when old and new tubing were compared. Interest in the matter — except for researchers — dropped off after it was discovered, by trial and error method, that a moderate amount of molybdenum in the alloy prevented brittleness after long service.

Some careful experiments on highly purified Fe-Cr alloys, described in 1931 by Adcock in *Journal* of the Iron and Steel Institute, did not locate anything but a continuous series of alpha solid solutions. More recently, American investigators of Fe-Cr-Si and other ternary systems have discovered ample evidence of a second phase, dubbed "sigma" ($\sigma$). Under these circumstances, it seemed desirable to re-examine Adcock's samples by the X-ray diffraction method, which clearly distinguishes between the very simple pattern *(Cont. on p. 128)*




# *RADIAMATIC Solves Control of*
# HIGH SPEED SALT BATHS

Closer temperature control of high speed salt baths at lower costs is being accomplished at Lorenz & Sons, Inc., Philadelphia, Pa.

The above illustration is typical of many Radiamatic installations where thermocouple maintenance has been eliminated.

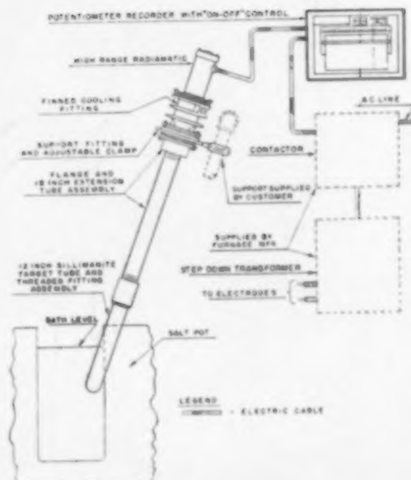
Users of Brown Radiamatic Pyrometers have found temperature measurement control by the radiation principle highly accurate and dependable. It safeguards against thermocouple protecting tube failure, which can cause serious damage to recording instrument if subjected to the high A.C. potential in salt bath. The use of a sillimanite target tube insures long life and makes it possible to continuously measure deep bath temperatures.

Extremely responsive — accuracy is unaffected by dust, dirt, fumes or corrosive atmospheres.

The Radiamatic is self-contained — measures temperatures beyond the range of conventional thermocouples—built-in compensator compensates for ambient temperature changes up to 250° F.

*Water-cooling is unnecessary with the Radiamatic on high speed salt baths—easy to install—universal in application.*

Write for Bulletin 5101—The Brown Instrument Company, *a division of Minneapolis-Honeywell Regulator Company*, 4503 Wayne Avenue, Philadelphia 44, Pennsylvania. Offices in all principal cities. 119 Peter Street, Toronto, Canada — Wadsworth Road, Perivale, Middlesex, England—Nybrokajen 7, Stockholm, Sweden.




**BROWN RADIAMATIC PYROMETER**

## Sigma Phase

*(Cont. from page 126)* produced by the alpha solid solution and the very complicated pattern of the sigma phase. This has now been done by A. J. Cook and F. W. Jones in the British National Physical Laboratory. They find, incidentally, that structural changes occur much more slowly in bars or sticks than in heavily cold worked powders filed from them.

Briefly their conclusions are that the alpha phase is stable in pure binary iron-chromium alloys above 820° C. (1510° F.) at the 600° C. (1110° F.) level, the sigma phase only is found in well annealed alloys between 44 and 50 atomic % chromium; at that same temperature, duplex alpha plus sigma structures exist at 26 to 44 atomic % chromium on the one side, and 50 to 71% on the other (a range of composition much wider than reported by German scientists). The alpha boundary, then, consists of a parabola, open downward with axis vertical at about 47 atomic % chromium, reaching as far up as 820° C. and the two branches passing through 26 and 71% at the 600° C. level. The sigma boundary is a much narrower parabola on the same axis, tangent at the 820° C. level, and its two branches passing through 44 and 50 atomic % chromium at the 600° C. level.

A pronounced hysteresis effect occurs in the temperature range from 770 to 820° C. (1420 to 1510° F.). For example, an alloy containing 47 atomic % chromium—about median composition of pure sigma phase — can be converted by appropriate heat treatments into pure alpha (annealing at 900° C.), pure sigma (annealing at 600° C.) or a mixture of alpha and sigma (brief heating of an alpha specimen at 750° C.). If these samples are then annealed for 7 days at 780° C. (1435° F.), 17 days at 800° C. (1475° F.) or 26 days at 810° C. (1490° F.) no change could be detected in the structure of any of the three. "The fact that either the alpha or the sigma phase can exist for such long periods without any noticeable change [in a region where theoretically sigma is the stable phase] suggests that this is a case of true hysteresis and is not merely due to a very high 'time of relaxation'; there is, therefore, very little possibility of accurately establishing the phase boundaries in this temperature interval."

# What a VARIETY of HEAT TREATING You Can Handle with DESPATCH FURNACES

● Set the controls at *any* heat from 275°F. to 1400°F.—whatever metallurgists' specs require—and you'll get the heat treatment the charge needs, *with your Despatch furnace.*

You don't need to worry about results, regardless of the type of load or the heat treating process involved. It may be a dense load of high-carbon steel parts needing fast, uniform penetration of heat. Or you may have a batch of aluminum or magnesium-alloy castings requiring smooth high-volume airflow to give "straight-line" heat control and uniform temperature throughout every inch of the chamber.

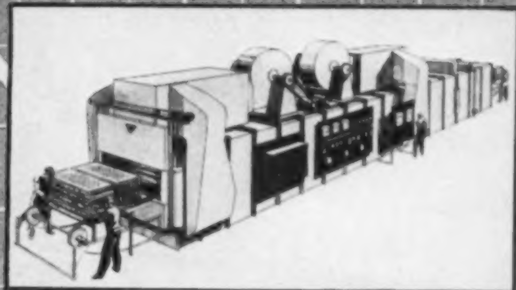
Whatever the process, the Despatch-engineered heating system will do the job with laboratory accuracy! And you can use the *same* furnace for all your heat treating jobs within the temperature range.

**Investigate Despatch-engineered furnaces today** . . . Their unique method of heat supply, control and distribution provides amazing flexibility for different processes, heat-treats more loads-per-day, meets *all* specifications — and does every job with economical use of labor and fuel.

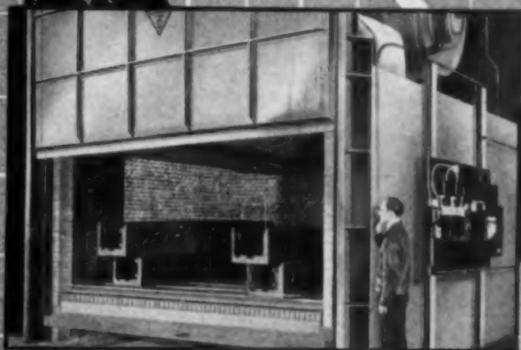
STRAIGHT LINE CONTROL

Despatch furnace for heat treating magnesium and aluminum castings. Note elevator and quench.

UNIFORMITY



Despatch furnace for processing aircraft sheets. Transports, heat treats and quenches automatically.



Despatch gas-fired carbottom-type furnace for stress relieving weldments. Has program control.

SPEEDY PROCESSING

Battery of Despatch gas-fired pit-type furnaces for heat treating bearings. 32 standard models.

FLEXIBLE CONTROL

**These HEAT TREATING PROCESSES are handled BETTER by DESPATCH Forced-Convection FURNACES**

●

SOLUTION HEAT TREATING
PRECIPITATION HEAT TREATING
TEMPERING & DRAWING
AGING
STRESS RELIEVING
NORMALIZING

*If you have a heat treating problem . . .*
**WRITE TODAY FOR A DESPATCH BULLETIN**

**DESPATCH**
OVEN COMPANY MINNEAPOLIS

## Welds in German Tank Armor*

By Col. Scott B. Ritchie

AN EXAMINATION of German welded armor in the field disclosed a few cases where cracks in welds had been repaired before the vehicle had been captured or become a complete casualty. It does not appear that the old welds are cut out before the repair is made. Workmanship is rough and normally ferritic electrodes are used. While it is reported that the welds in German tanks perform well under normal service conditions, it is known that the behavior of the welding in German PzKw III and PzKw IV tanks under artillery fire has been somewhat erratic. Some of the welds, after repeated hits on the vehicle, give little indication of failure; in others, cracks develop in joints even after a single hit. These cracks may run for considerable distance along the joint.

Armor 11 mm. (0.436 in.) thick, taken from a German PzKw III tank in January 1943, was found to be cross-rolled, homogeneous and good quality steel, quenched and drawn to 320 to 340 Brinell. This armor is similar to S.A.E. 4150 and to some of the armor that was used in this country for riveted and bolted fabrication. Fragments in the heat-affected zone adjacent to the weld metal had a maximum hardness of 690 Vickers. In the weld metal itself the maximum hardness observed was 446 Vickers. The welding procedure employed was apparently two-pass sequence. Excessive porosity was observed and it was more prevalent at the fusion line between the two weld layers. Lack of fusion was especially noticeable between the base metal and the first pass. The chemical analysis of the plate was C 0.44%, Si 0.25%, Cr 1.30%, Mo 0.50%, V 0.17%, Cu 0.18% and Ni trace. *(Cont. on page 132)*

*Extracts from "Welded Weapons in War", presented at the October 1943 meeting of the American Welding Society. *The Welding Journal*, November 1943, page 893.

## German Armor

*(Cont. from p. 130)* The composition of the armor of a "Tiger" tank ran around 0.50% C, 2.50% Cr, and 0.60% Mo; this was wrought homogeneous armor with hardness of about 325 Brinell.

The German conception of an armor weldment is quite different, apparently, from ours. It appears that our enemies make an effort to develop a hardness in the weld metal equivalent to that of the base metal. Composition of the weld metal is markedly different from that used in this country, and is interesting because of the high alloy content in the ferritic type weld. In one of the German maintenance vehicles taken in Tunisia we found welding rod, some coated and some bare. The bare rods all appeared to be plain low carbon steel. Likewise, the core wires of the coated rods were plain low carbon steel, but the presence of silicon and chromium in the coating suggests the possibility of a hard facing electrode.

Some of the salient characteristics of German welding observed so far are:

1. Mortised joints.

2. Non-uniform quality of welding, with most of it decidedly inferior to ours as judged by ballistic performance.

3. Susceptibility of failure in the fusion zone of welds under shock conditions in which the welding bead breaks from the base metal, sometimes coming out as a strip.

4. In some joints the notch was not completely filled, flush to the surface of face-hardened armor. Usually the weld metal is from $\frac{1}{16}$ to ¼ in. *below* surface of plates about 2 in. thick.

5. In cases where notch is completely filled, the root deposit is of 18-8 austenitic steel with hardness of about 280 Vickers; the center deposit is ferritic or low alloy with a hardness of approximately 440 Vickers; the top deposit is of C-Ni-Cr-Mn-W type with approximate hardness of 525 Vickers.

6. The Germans first used homogeneous plates, then homogeneous plates *(Cont. on p. 136)*

## German Armor

*(Starts on p. 130)* plus preferential face-hardened plates bolted over the homogeneous plates and separated from them by thin washers; then a combination of two face-hardened plates separated 4 to 6 in. by spacers welded to the inside plates. (Outside plates were bolted to the spacers.) This indicated that our enemies attempted to improvise to meet changing requirements imposed by our improved projectiles and anti-tank weapons.

## Architectural Aluminum *

By G. O. Taylor

ALUMINUM and certain of its alloys are admirably suited for architectural purposes, and have been used more extensively than is generally known. The lightness of aluminum, the variety of forms available, the ease of fabrication, and the diverse surface finishes obtainable offer outstanding potentialities to the architect and craftsman — when corrosion resistance is assured by well-proven and economical methods.

The type of aluminum alloy most favored for architectural metal work in Great Britain is that containing from 2 to 9% of magnesium, with or without the addition of small quantities of other elements, such as manganese or chromium. These alloys do not need any heat treatment to possess their maximum mechanical properties, the strength being controlled by the magnesium content and the degree of cold work during fabrication. Very high tensile strength, exceeding that of mild steel, can be obtained in wrought forms, with magnesium contents of 6 to 9%, but only at the expense of workability.

The alloys containing from 2 to 4% magnesium are most favored. They are reasonably strong and sufficiently ductile to withstand a considerable degree of cold deformation. They have the highest resistance to corrosion yet available in light alloy materials.

**Fabrication** — These alloys can be produced in all forms, including complicated extruded *(See p. 140)*

---

*Abstracted from "Aluminum in Architecture of the Future", by G. O. Taylor, *Metallurgia*, February 1943, p. 147.

**100% QUALITY CHECKUP...**

PACKAGED WELDING ELECTRODES CHECKED FOR METALLURGICAL UNIFORMITY BY MEANS OF THE

**DuMONT *Cyclograph***

***Reports the INTERNATIONAL NICKEL COMPANY:***

"Recently we had occasion to inspect approximately 150,000 pounds of welding electrodes for magnetic properties. Intended for highly specialized use, this material was packaged in five-pound wax-sealed bundles. Had we checked the two million individual rods, it would have been necessary to destroy the packages. Also, a large crew of men would have spent days doing the job.

"Instead, the Cyclograph made it possible for us to inspect all this material in four days, with but one or two stockroom attendants. After this inspection it was of course possible to retain the non-magnetic material in the original *undamaged* and *unopened* packages.

"According to Cyclograph findings, a total of 2,672 pounds possessed magnetic properties. In subsequent rechecking of individual rods in the separated bundles by means of a magnet, one entire bundle was found to be magnetic, while at the other extreme only one rod showed magnetic properties. 70 rods to each bundle. Yet even a single magnetic rod could easily be detected regardless of its position in the bundle!

"Aside from marked savings in manhours and expense, the Cyclograph made it possible for our customers to proceed without interruption or delay in the processing of vital war equipment, with complete assurance of 100% uniformity in welding electrodes."

• • •

All of which is once more indicative of the possibilities of this new metallurgical checking, inspection and sorting technique.

**Write for Literature...**



**DUMONT** *Precision Electronics & Television*

ALLEN B. DU MONT LABORATORIES, INC., PASSAIC, NEW JERSEY • CABLE ADDRESS: WESPEXLIN, NEW YORK

## Aluminum

*(Cont. from page 136)* sections, thin drawn sections, sections drawn on wood cores, thick or thin rolled sheets, all shapes and commercial sizes of tubing, wire, rivets, nuts and bolts, wire mesh and woven screens. (Sand or die castings can be made of appropriate alloy compositions for individual items.)

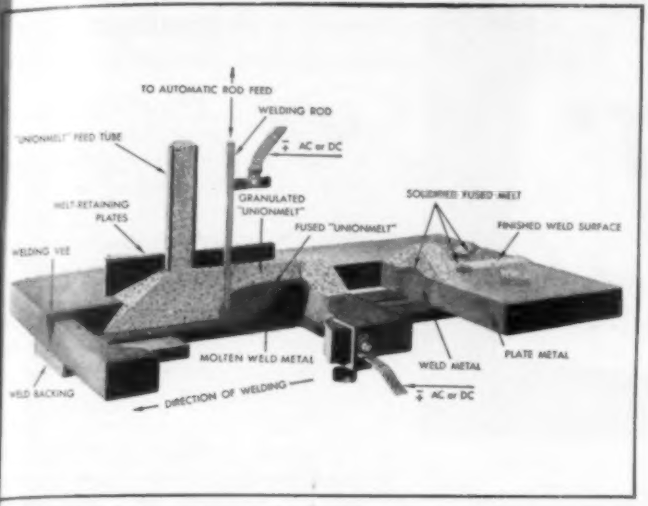
Manipulation of extrusions does not present any difficulty, since the alloys can be worked in a manner similar to that adopted for mild steel. Some deformation can be carried out with the metal in cold condition; when necessary it is softened in the region of deformation by heating to about 625° F. All normal machining can be carried out with ease; slight alterations in tool design are sometimes necessary for highest speeds.

Welding rod should be of the same composition as the members to prevent a difference of color at the joint. Even then the deposited metal sometimes shows a crystalline structure due to slight etching in subsequent anodizing. The work should be chamfered from the back, so that a minimum of deposited metal is evident at the front surface. Soldering demands a special technique and special solders, and is not recommended for anodic finishing or for outdoor use, unless the joints can be protected.

**Surface Finishes** in great variety can be applied to aluminum and the aluminum-magnesium alloys — greater, indeed, than is possible with any other metal used in architecture. The most popular mechanical finish is that resulting from polishing or buffing operations. Where the atmosphere tends to be warm but humid, the aluminum-manganese alloys require far less maintenance than other alloys in order to retain their polished surface. Even when continually handled, as door frames and handrails, the aluminum-manganese alloys are immune from tarnishing. Outdoors in an industrial atmosphere these outstanding properties are revealed to the best effect.

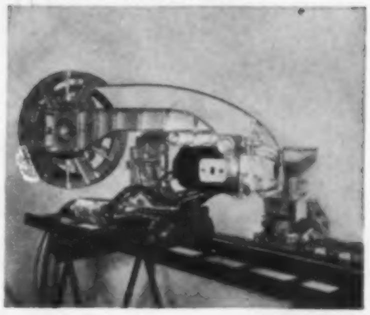
The electrochemical process of anodic oxidation has superseded all purely chemical immersion processes for decorative surface coatings. The anodic film is a natural mordant for dyestuffs.

By variation of process factors and preparatory finish given to the metal surface, the anodic oxidation process provides *(Cont. on p. 144)*

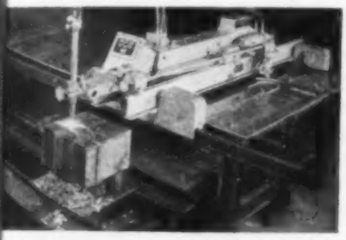



This sketch shows how a UNIONMELT butt weld is made.

## UNIONMELT WELDING



UNIONMELT electric welding is a unique automatic process that makes welds of unusually high quality in any thickness of metal at high speeds. Once the speed and current values are established by the operator, the "human element" is eliminated as a factor in producing good welds. UNIONMELT welding is done under a protective blanket of a special granulated material—without flash, glare, or sparks. The rod is fed automatically as work progresses and is thoroughly mixed with the molten base metal. For these reasons, UNIONMELT welding is widely used in the fabrication of pressure vessels, pipe, railroad equipment, tankers, and ships.

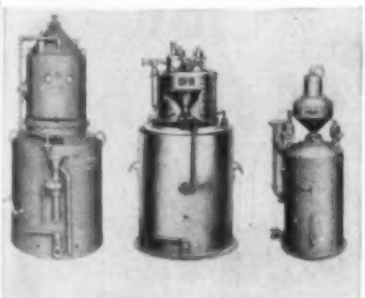


## MACHINE APPARATUS

Included in the OXWELD line of apparatus are portable and stationary oxy-acetylene machines for cutting shapes or straight lines; flame-hardening apparatus; bar and billet cut-off machines; automatic welding equipment; and tractor units for plate-edge preparation.

## WELDING RODS AND SUPPLIES

The many kinds and sizes of OXWELD high quality welding rods make it possible to select the one that will give best results on each job. The OXWELD line also includes fluxes, gloves, goggles, lighters, hose, and asbestos paper. Rods and supplies may be ordered from Linde or from automotive and industrial jobbers.



## GENERATORS AND MANIFOLDS

OXWELD acetylene generators are made for both portable and stationary use — with maximum generating capacities of from 30 to 9,000 cu. ft. per hour. OXWELD manifolds centralize the oxygen and acetylene supply from cylinders.

## HAND APPARATUS

Oxy-acetylene apparatus which may be ordered from Linde includes oxy-acetylene blowpipes for all welding and heating work; oxy-acetylene cutting blowpipes, cutting attachments, and nozzles; and oxy-acetylene descaling and flame-priming equipment. OXWELD apparatus is supplied from Linde offices and warehouses. The PUROX and PREST-O-WELD line, and PREST-O-LITE air-acetylene appliances for soldering and brazing, are distributed by industrial and automotive jobbers.

## OXYGEN, ACETYLENE, CARBIDE

A booklet describing use of LINDE oxygen, PREST-O-LITE acetylene, UNION carbide, and OXWELD apparatus in these and other processes will be sent without charge on request. Ask for Form 5268A.

**BUY UNITED STATES WAR BONDS AND STAMPS**

# THE LINDE AIR PRODUCTS COMPANY

*Unit of Union Carbide and Carbon Corporation*

30 E. 42nd St., New York 17, N. Y. UCC Offices in Other Principal Cities

In Canada: Dominion Oxygen Company, Limited, Toronto

## Aluminum

(Starts on p. 136) a wide range stainless, wear resistant finish ranging through natural colors su as frosted silver, silver matte, an antique silver to all the myria colors that can be obtained by dy stuff combinations. By maskin stenciling and etching processe multi-color, printed or patterne designs can be reproduced, so th the decorative possibilities are vi tually unlimited.

Colored anodized finishe exposed indoors remain goo indefinitely, but the range of color fast to sunlight and weather fo exterior uses is more restricted.

The uses of light metals i architecture of the future wi undoubtedly be many and varied both for structural and decorativ purposes. Cast aluminum allo facings have the important advan tage that since the corrosion prod ucts of aluminum are colorless surrounding stonework can neve become stained or discolored Another application in which con siderable development is likely i the application of corrosion resist ing alloys to cast ornamentation statuary and monuments. Materia anodized to a silver finish has been extensively used for doors, window framing, panels, spandrels, grills and escalator casings.

# WHAT'S NEW

## IN MANUFACTURERS' LITERATURE

### METAL WORKING • FABRICATION

*Powdered metal presses.* Kux Machine Co. Bulletin 1.

*Forging presses.* Ajax Mfg. Co. Bulletin 2.

*Horizontal extrusion presses.* Hydropress, Inc. Bulletin 3.

*36-page pictorial story* of the Cecostamp. Chambersburg Engineering Co. Bulletin 4.

*Cutting Oils.* Cities Service Oil Co. Bulletin 5.

*Presses* for Powder Metallurgy. F. J. Stokes Machine Co. Bulletin 7.

*Information and data* on straightening press. Anderson Bros. Mfg. Co. Bulletin 10.

*Properties* and uses of cutting oils. Gulf Oil Corp. Bulletin 8.

*Surface coated abrasive belts.* Minnesota Mining & Mfg. Co. Bulletin 12.

*Savings in oils,* tool bits, grinding wheels. Sparkler Mfg. Co. Bulletin 15.

*New catalog* illustrates standard, non-standard, and special tools. Kennametal, Inc. Bulletin 250.

*Mounted wheels,* Handee and Hi-Power tools. Chicago Wheel & Mfg. Co. Bulletin 21.

*Air tools in steel mills* and foundries are pictured in new booklet by Ingersoll-Rand. Bulletin 255.

*Complete and valuable study* of "Machining of Metals", including chip formation, is offered by National Refining Co. Bulletin 335.

*Safe-T tongs* and their use in materials handling are described in new booklet by Heppenstall Co. Bulletin 434.

*63-page pocket booklet* shows useful tables of weights and measures used in the metal industry. Mesta Machine Co. Bulletin 441.

*Practical data sheet* describes cutting and grinding compound. Diversey Corp. Bulletin 447.

*8-page general catalog* outlines the hard facing alloys and overlay metals of this company, with many illustrations and typical applications. Wall-Colmonoy Corp. Bulletin 484.

*Attractive 16-page booklet* describes the new "MX" grinding tools, citing many features and applications. Carborundum Co. Bulletin 518.

*Struthers Wells Corporation's* Tangent Bender and its ability to edge bend sheet metal in the lighter gauges is described in illustrated 8-page leaflet. Bulletin 520.

*This company has issued* two ne[w] booklets showing new price lists [for] sintered carbides. Firth-Sterli[ng] Steel Co. Bulletin 486.

*"Quality Control"* is the title [of] this new 64-page pocket size han[d]book on scientific inspection. Co[n]tinental Machines, Inc. Bulletin 47[…]

*20-page booklet discusses* typic[al] problems involved in the selecti[on] and application of water-mix oils. [D.] A. Stuart Oil Co., Ltd. Bulletin 4[…]

*Attractive new bulletin* describ[es] the Spencer Turbine Co.'s Sump-Va[c,] a new portable vacuum produc[t] which is said to clean machine su[mp] tanks in 2 to 10 min. Bulletin 4[…]

### FERROUS METALS

*Republic Steel Corp.'s* second e[di]tion of National Emergency Ste[els] tells you all about these new stee[ls.] Bulletin 345.

*Page after page* of useful technic[al] data and reference tables on to[ol] steels. Latrobe Electric Steel C[o.] Bulletin 367.

*Steel Data Sheets.* Wheelock, Lo[ve]joy & Co. Bulletin 25.

**Use Handy Coupon Below for Ordering Helpful Literature.**

**Other Manufacturers' Literature Liste[d] on Pages 166, 168, 170, 172, 174, 176, 1[78,] 180, 182, 184, 186, 188, 190 and 1[…]**

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**Metal Progress 7301 Euclid Ave., Cleveland 3, Ohio** July, 19[…]

**Send me the Literature I have indicated below.**

**Name** ........................................ **Title** ........................................

**Company** ........................................ **Address** ........................................

(Students—please write direct to manufacturers).

Check or circle the numbers referring to literature described on these 15 pages.

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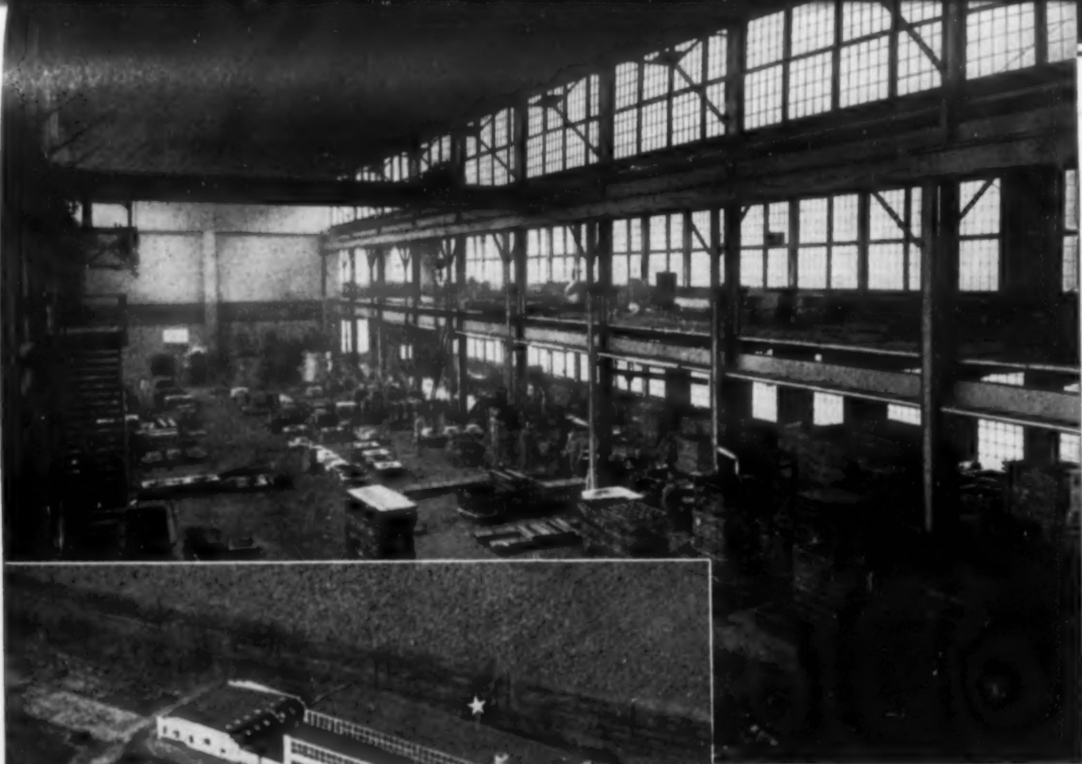
| 2 | 51 | 98 | 141 | 173 | 208 | 322 | 362 | 404 | 448 | 478 | 503 | 524 |
| 3 | 56 | 99 | 142 | 175 | 213 | 323 | 363 | 406 | 450 | 479 | 504 | 525 |
| 4 | 59 | 101 | 143 | 176 | 215 | 324 | 364 | 407 | 452 | 480 | 506 | 526 |
| 5 | 62 | 102 | 146 | 177 | 240 | 325 | 365 | 409 | 453 | 482 | 507 | 527 |
| 7 | 65 | 103 | 147 | 179 | 246 | 327 | 366 | 410 | 454 | 483 | 508 | 528 |
| 8 | 66 | 106 | 148 | 180 | 250 | 328 | 367 | 411 | 455 | 484 | 509 | 529 |
| 10 | 67 | 107 | 149 | 182 | 255 | 329 | 368 | 422 | 457 | 486 | 510 | 530 |
| 12 | 70 | 114 | 150 | 183 | 258 | 331 | 369 | 424 | 458 | 487 | 511 | 531 |
| 15 | 71 | 115 | 152 | 185 | 271 | 333 | 372 | 426 | 459 | 489 | 512 | 532 |
| 21 | 72 | 116 | 154 | 186 | 288 | 335 | 374 | 428 | 461 | 490 | 513 | 533 |
| 25 | 78 | 117 | 155 | 190 | 292 | 337 | 375 | 433 | 462 | 491 | 514 | 534 |
| 26 | 79 | 118 | 156 | 192 | 296 | 338 | 376 | 434 | 463 | 492 | 515 | 535 |
| 30 | 82 | 119 | 158 | 193 | 297 | 339 | 380 | 436 | 465 | 493 | 516 | 536 |
| 31 | 85 | 123 | 161 | 197 | 301 | 343 | 383 | 437 | 466 | 494 | 517 | |
| 33 | 86 | 128 | 162 | 199 | 305 | 345 | 384 | 438 | 469 | 495 | 518 | |
| 35 | 89 | 132 | 164 | 200 | 307 | 347 | 385 | 440 | 470 | 497 | 519 | |
| 40 | 93 | 134 | 167 | 201 | 314 | 353 | 388 | 441 | 471 | 499 | 520 | |
| 41 | 94 | 135 | 170 | 203 | 316 | 354 | 390 | 445 | 472 | 500 | 521 | |
| 42 | 96 | 137 | 171 | 204 | 318 | 359 | 398 | 446 | 475 | 501 | 522 | |



No better alloy plant than this 11 acre plant exists anywhere.

*A new 110 ft. addition, not shown in above photos, was completed in January.

## *WHAT'S NEW*
### IN MANUFACTURERS' LITERATU

*Molybdenum wrought steel* Molybdenum Corp. of America. Bu letin 26.

*Free Machining Steels.* Monar Steel Co. Bulletin 30.

*Chemical analyses,* shapes an sizes of Joslyn stainless steel pro ucts. Joslyn Mfg. and Supply C Bulletin 297.

*Tool Steels.* Bethlehem Steel C Bulletin 31.

*Enameling iron sheets.* Inlan Steel Co. Bulletin 33.

*Loose-leaf reference book* on mo lybdenum steels. Climax Molybde num Co. Bulletin 35.

*Aircraft Alloy Steels.* Joseph T Ryerson & Son, Inc. Bulletin 40.

*Kinite alloy tool steel bar stock.* Boker & Co., Inc. Bulletin 258.

*New Catalog C* makes it easy to ge International Nickel Co. literature, a it presents brief description and in dex to a wide variety of booklet Bulletin 305.

*"Graphitic Booklet"* gives complet information on new, free-machinin long-wearing steel. Steel & Tub Div., Timken Roller Bearing C Bulletin 307.

*HWD hot work die steel* and Ste ling stainless steels are described i four new leaflets by Firth-Sterlin Steel Co. Bulletin 323.

*Engineering* and comparative in formation on porcelain enamele iron is presented in new illustrate booklet by American Rolling Mill C Bulletin 376.

*New booklet* gives full informatio on N-A-X high tensile and N-A 9100 Series of alloy steels. Gre Lakes Steel Corp. Bulletin 328.

*Attractive new catalog* describ the line of steel offered by Peni sular Steel Co. Bulletin 337.

*Spindle speed calculator* is hand chart to figure machining rates o bar steels. Bliss & Laughlin, In Bulletin 333.

*64-page booklet* describes th welding of stainless steels. Alle gheny Ludlum Steel Corp. Bulleti 384.

*84-page tool and die* steel handboo just issued by Ziv Steel & Wire C is a helpful guide to selection, trea ment and use of these importan steels. Bulletin 440.


Use Handy Coupon on Page 164 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 164, 168, 170, 172, 174, 176, 17 180, 182, 184, 186, 188, 190 and 19

# *WHAT'S NEW*

**IN MANUFACTURERS' LITERATURE**

*32-page booklet* which pictorially and textually amounts to a scientific treatise on two carbon steels—Speed Case and Speed Treat—has been issued by W. J. Holliday & Co. Bulletin 450.

*Fitzsimons Co.* issues interesting leaflet on speed case and speed treat steels. Bulletin 452.

*Molybdenum-Tungsten high speed* steels marketed under the general trade name Mo-Max are discussed comprehensively in 52-page book by J. V. Emmons, metallurgist for the Cleveland Twist Drill Co. Bulletin 497.

*Carpenter Steel Co. offers* a convenient four-color chart useful in identifying various types of stainless steels which may have become mixed in stock. Bulletin 507.

*Latest data chart,* Section D, No. 1, shows government "specs" for alloy steels and corresponding commercial designations. Peter A. Frasse & Co., Inc. Bulletin 533.

## NON-FERROUS METALS

*This "Aluminum Imagineering Notebook"* presents 12 important economic advantages of aluminum and illustrates numerous examples of things which have been imagineered into aluminum actualities. Aluminum Co. of America. Bulletin 472.

*80-page pipe and tube* bending handbook has been issued by Copper & Brass Research Assn. Bulletin 399.

*Platinum Metal Catalysts.* Baker & Co., Inc. Bulletin 41.

*Die casting equipment.* Lester-Phoenix, Inc. Bulletin 42.

*Copper Alloys.* American Brass Co. Bulletin 45.

*6th edition of Revere Weights* and Data Handbook. Revere Copper and Brass, Inc. Bulletin 296.

*Rare metals,* alloys and ores. Foote Mineral Co. Bulletin 56.

*Dowmetal data book.* Dow Chemical Co. Bulletin 51.

*Two new Ampco Metal data sheets* discuss forging Ampco to improve physical characteristics and use of Ampco for non-scratching feed fingers. Bulletin 314.

*Printed information on Lithium* of interest to nonferrous and physical metallurgists is available from Lithaloys Corp. Bulletin 532.


**Use Handy Coupon on Page 164 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 164, 166, 170, 172, 174, 176, 178, 180, 182, 184, 186, 188, 190 and 192.**

## *WHAT'S NEW*

**IN MANUFACTURERS' LITERATU**

*Sheet and strip aluminum* is di cussed in this 8-page booklet, givi tolerances, specifications, weigh chemical composition and physic properties. Reynolds Metals Co. Bu letin 524.

*"Some Considerations* in Maki Test Bars" is the title of an intere ing booklet by Federated Metals Di American Smelting and Refining C Bulletin 529.

*"Designing with Magnesium"* is t tle of new book offered by Americ Magnesium Corp. Bulletin 433.

*Red-X Aluminum Alloys,* produce by the largest single producer c Commercial Aluminum and Magn sium Alloys, the National Smelti Co., are described, applications stu ied, in this 16-page file folder. Bu letin 499.

*Facts on Beryllium Copper,* inclu ing composition, forms availabl applications and extensive addition information are presented in th new 16-page booklet by the Rive side Metal Co. Bulletin 511.

### WELDING

*40-page catalog* reviews the pro ress and many applications of lo temperature welding. Eutectic Wel ing Alloys Co. Bulletin 471.

*Welding Stainless.* Page Steel Wire Div., American Chain & Cab Co., Inc. Bulletin 59.

*Oxy-acetylene welding* and cuttin Linde Air Products Co. Bulletin

*Welding and brazing* of aluminu a new data book issued by Alum num Co. of America. Bulletin 66.

*Data book facts* on spot, seam a flash welding ferrous and non-fe rous metals and alloys. P. R. Ma lory & Co., Inc. Bulletin 65.

*Shield Arc electrodes.* McKay C Bulletin 67.

*Nu-Braze No. 4,* an improved silv brazing alloy. Sherman & Co. Bull tin 288.

*Two new hard-facing alloys* fu nished as welding rods for applic tion by Oxy-Acetylene process a described by the Stoody Co. in Bu letin 325.

*Comparable arc welding electrod* for stainless are shown in cha issued by Alloy Rods Co. Bulletin 35

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Other Manufacturers' Literature Listed on Pages 164, 166, 168, 172, 174, 176, 17 180, 182, 184, 186, 188, 190 and 19

## *WHAT'S NEW*
### IN MANUFACTURERS' LITERATURE

*Helpful electrode color chart* is offered by the Arcos Corp. Bulletin 374.

*Arc welding* inspection chart, designed so that operators can tell at a glance whether welds are being properly made, has been issued by the Lincoln Electric Co. Bulletin 411.

*New Phos-Copper booklet* explains ways to braze, design and applications. Westinghouse. Bulletin 455.

*16-page booklet* describes welding and cutting equipment. Victor Equipment Co. Bulletin 489.

*Bulletin No. 14*, "How To Repair Broken Cutting Tools With Easy-Flo", is filled with practical, instructional copy, profusely illustrated. Handy & Harman. Bulletin 506.

*Air Reduction Sales Co.* offers 20-page revised price list, "Gas and Electric Welding Supplies and Accessories". Bulletin 512.

*32-page booklet presents* numerous experience reports from large users of arc welding. General Electric Co. Bulletin 513.

*Pocket-sized*, slide-type guide showing proper tip sizes, gas pressures, and other data required for machine gas-cutting steel is offered by Air Reduction. Bulletin 527.

### TESTING & INSPECTION

*Latest technical literature* on x-ray and radium protection, together with lead products catalog, has been issued by Bar-Ray Products, Inc. Bulletin 463.

*The Bristol-Rockwell* dilatometer and its use is described in this leaflet by The Bristol Co. Bulletin 465.

*Metallurgical polishing equipment* offered by Precision Scientific Corp. is described in illustrated booklet. Bulletin 359.

*Various methods* and specific applications of the measurement of case depth are described in illustrated pamphlet offered by Allen B. DuMont Laboratories, Inc. Bulletin 339.

*Bibliography* of more than 700 papers dealing with the polarographic method of metal analysis and a booklet discussing this equipment is offered by E. H. Sargent & Co. Bulletin 338.


Use Handy Coupon on Page 164 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 164, 166, 168, 170, 174, 176, 178, 180, 182, 184, 186, 188, 190 and 192.

## *WHAT'S NEW*

**IN MANUFACTURERS' LITERATURE**

*SR-4 strain gage* and illustrations of its many uses. Baldwin Southwark. Bulletin 70.

*New book* contains wealth of practical, usable information on industrial inspection by x-ray. Westinghouse Electric & Mfg. Co. Bulletin 71.

*X-Ray Diffraction Unit.* General Electric X-ray Corp. Bulletin 72.

*Inspection* of non-magnetic metals with the new Zyglo method. Magnaflux Corp. Bulletin 78.

*Industrial radiography* with radium. Canadian Radium & Uranium Corp. Bulletin 79.

*Portable Brinell hardness tester* and folding Brinell microscope. Andrew King. Bulletin 85.

*Universal testing machines* and typical uses. Riehle Testing Machine Div., American Machine and Metals, Inc. Bulletin 86.

*Optical Aids.* Bausch & Lomb Optical Co. Bulletin 94.

*Metallographic polishing powder.* Conrad Wolff. Bulletin 96.

*Metallurgical Equipment.* Adolph I. Buehler. Bulletin 97.

*"Radiography of Materials"* is title of new 96-page book on industrial radiography. Eastman Kodak Co. Bulletin 331.

*Stresscoat,* a method of analyzing distribution, direction and value of local strains. Magnaflux Corp. Bulletin 301.

*Hardness testing equipment.* Wilson Mechanical Instrument Co., Inc. Bulletin 98.

*Attractive, illustrated booklet* describes Clark Instrument's precision hardness tester. Bulletin 318.

*High intensity* industrial illuminator is illustrated and described in new leaflet by Kelley-Koett Mfg. Co. Bulletin 406.

*30th Anniversary Catalog* shows the special metallurgical equipment offered by Claud S. Gordon Co. Bulletin 410.

*Laboratory* and industrial pH meters are described and explained in leaflet issued by Beckman Instruments Division. Bulletin 422.

*8-page illustrated leaflet* describes line of industrial instruments offered by the Brush Development Co. Bulletin 428.


Use Handy Coupon on Page 164 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 164, 166, 168, 170, 172, 176, 178, 180, 182, 184, 186, 188, 190 and 192.

## *WHAT'S NEW*

**IN MANUFACTURERS' LITERATU**

*Details and various applications* the portable tensile tester are show in 8-page leaflet by W. C. Dillon Co., Inc. Bulletin 491.

*Advantages and speed* of testi with the Magnetic Analysis Corp Comparator are described and pi tured in brochure just released. Bu letin 492.

*6-page leaflet describes* the co stant temperature equipment offer by American Instrument Co. Bu letin 493.

*New Carbon and Sulphur* Dete minator is described in this ne 8-page leaflet. Harry W. Dietert C Bulletin 501.

*Many tips and suggestions* f industrial laboratories are present in 24-page March issue of "Curv and References" by Wilkens-Ande son Co. Bulletin 502.

*4-page folder* on the inspectio and control of surface finish offered by George Scherr Co. Bu letin 508.

*New Norelco* electronic Searchr Modal 150 is described and sever features illustrated in this 4-pa leaflet. North American Philips C Inc. Bulletin 517.

*New 50 KV industrial x-ray un* its features and applications, a presented in this 8-page leafle Picker X-Ray Corp. Bulletin 525.

### TEMPERATURE CONTROL

*Potentiometer temperature* indic tors. Foxboro Co. Bulletin 82.

*Micro-Optical Pyrometers.* Pyro eter Instrument Co. Bulletin 89.

*Pyrometer control* of high spe salt baths is described in new boo let by Brown Instrument Co. Bull tin 324.

*Industrial thermocouples.* Arkl S. Richards Co. Bulletin 93.

*Operating principle* and typ available of the synchronous-moto driven cam program timer are co ered in this new 4-page folde Automatic Temperature Control C Inc. Bulletin 487.

*36-page thermocouple* data boo and catalog describes product prices and presents recommend tions for thermocouple users. Whee co Instruments Co. Bulletin 490.

Use Handy Coupon on Page 164 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 164, 166, 168, 170, 172, 174, 17 180, 182, 184, 186, 188, 190 and 19

# *WHAT'S NEW*

## IN MANUFACTURERS' LITERATU

*The Bristol Co. announces* a ne bulletin B220 describing its new li of Free-Vane Electronic Controlle for temperature, pressure, liqu level and humidity. Bulletin 503.

*48-page revised catalog,* "Microm and Speedomax Rayotube Pyro eters", pictures applications of th equipment to important new te perature-measuring jobs. Leeds Northrup Co. Bulletin 514.

*Many types* of pyrometers and te perature controllers are illustrate in this 4-page leaflet by Illinois Tes ing Laboratories, Inc. Bulletin 51

## HEATING • HEAT TREAT MENT

*"Isothermal Quench Baths* Applie to Commercial Practice" is the tit of this 12-page paper, a practic and useful discussion of S curves i heat treatment. Ajax Electric Co Inc. Bulletin 461.

*32-page booklet* describes 16 inte esting industrial uses of high fr quency electrical induction. Ohi Crankshaft Co. Bulletin 459.

*Quenching oil coolers* in heat trea ing practices are described in th leaflet by the Sims Co. Bulletin 46

*New catalog No. 406* describ Rockwell valves for control of ai gas and liquids. W. S. Rockwell C Bulletin 466.

*Neutral baths* for heat treatme and details of their use are describ in this booklet by the A. F. Hold Co. Bulletin 469.

*24-page technical data* and oper ing manual covering the Deepfree low temperature industrial chilli machines has been issued by Dee freeze Div., Motor Products Cor Bulletin 398.

*36-page catalog* illustrates Kol Hold line of thermal, sub-zero a stratosphere processing and testi machines. Kold-Hold Mfg. Co. Bull tin 99.

*Induction heating.* Induction Hea ing Corp. Bulletin 103.

*Internally heated salt bath furnac* and pots. Upton Electric Furna Div. Bulletin 102.

Use Handy Coupon on Page 164 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 164, 166, 168, 170, 172, 174, 17 180, 182, 184, 186, 188, 190 and 1

## *WHAT'S NEW*

**IN MANUFACTURERS' LITERATURE**

*8-page* pictorial bulletin describes the heat treating service of Continental Industrial Engineers, Inc. Bulletin 107.

*Electric Furnaces.* Ajax Electrothermic Corp. Bulletin 106.

*Lithco,* the chemically-neutral heat treating process, and Lithcarb, the process for fast, bright gas-carburizing. Lithium Corp. Bulletin 101.

*Furnaces for heat treatment* of aluminum, magnesium and their alloys. Lindberg Engineering Co. Bulletin 271.

*Gas, oil, and electric heat treating* and carburizing furnaces. Holcroft & Co. Bulletin 114.

*Industrial furnaces,* equipment for bright annealing stainless steels and ammonia dissociation equipment. Drever Co. Bulletin 115.

Industrial ovens, rod bakers, welding rod ovens, furnaces. Carl-Mayer Corp. Bulletin 116.

*Full muffle and other* heat treating furnaces described in catalog by Charles A. Hones, Inc. Bulletin 117.

*Non-metallic Electric* Heating Elements. Globar Div., Carborundum Co. Bulletin 119.

*56-page vest pocket data book* on heat treating practices and procedures. Chicago Flexible Shaft Co. Bulletin 118.

*Molten Salt Baths.* E. I. duPont deNemours & Co., Inc., Electrochemicals Department. Bulletin 123.

*Handling* cylinder anhydrous ammonia for metal treaters. Armour Ammonia Works. Bulletin 128.

*Certain Curtain Furnaces.* C. I. Hayes, Inc. Bulletin 134.

*Air-Oil Ratiotrol for proportioning* flow of fuel oil and air to oil burners. North American Mfg. Co. Bulletin 135.

*Two new bulletins* on vertical carburizers and on carbonia finish. American Gas Furnace Co. Bulletin 139.

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# *WHAT'S NEW*

## IN MANUFACTURERS' LITERATURE

*Controlled atmosphere furnace.* Delaware Tool Steel Corp. Bulletin 141.

*Dual-Action quenching oil.* Gulf Oil Co. Bulletin 132.

*Furnaces.* Tate-Jones Co. Bulletin 142.

*Industrial Carburetors.* C. M. Kemp Mfg. Co. Bulletin 143.

*Heat treating,* brazing and melting of ferrous and non-ferrous metals. Lepel High Frequency Laboratories, Inc. Bulletin 147.

*Vertical Furnace.* Sentry Co. Bulletin 148.

*Conveyor Furnaces.* Electric Furnace Co. Bulletin 149.

*High and low temperature* direct fired furnaces. R-S Products Corp. Bulletin 146.

*New Electric Furnace.* American Electric Furnace Co. Bulletin 150.

*Electric Furnaces* for laboratory and production heat treatment. Hoskins Mfg. Co. Bulletin 152.

*"The Lectrodryer* in the metallurgical industries," a new 4-page bulletin by Pittsburgh Lectrodryer Corp. Bulletin 155.

*Pictorial bulletin* describes furnaces for heat treating, normalizing, annealing, forging. Vulcan Corp. Bulletin 161.

*High Temperature Fans.* Michiana Products Corp. Bulletin 158.

*Protective combusted atmospheres* in Hevi Duty Electric Co. furnaces are discussed in 12-page Bulletin 316.

*Flame-type* mouth and taper annealing machine for steel cartridge cases. Morrison Engineering Corp. Bulletin 154.

*Turbo-Compressor data book* shows how to calculate compressed air systems for a dozen different applications. Spencer Turbine Co. Bulletin 329.



*No-Carb,* a liquid paint for prevention of carburization or decarburization. Park Chemical Co. Bulletin 156.

*Catalog* of heat treating materials. Heatbath Corp. Bulletin 322.

*Standardized sizes* of semi-muffle and pot-type furnaces are described and pictured in new leaflet by Dempsey Industrial Furnace Corp. Bulletin 354.

*Use of pulverized coal* in the metallurgical industries, equipment and designs, are described by Amsler Morton Co. in Bulletin 361.

*Rapid oil coolers* and heat transfer equipment are described in new catalog issued by Bell & Gossett Co. Bulletin 365.

*Laboratory and tool room furnaces.* Mahr Mfg. Co. in new Bulletin 327.

*82-page catalog* describes in detail General Electric heat treat furnaces. Bulletin 380.

*Illustrated bulletin* on stress-relieving, car-type furnaces. Radiant Combustion. Bulletin 375.

*Furnaces for heat treating* tools, dies and parts are described in new leaflet by Despatch Oven Co. Bulletin 362.

*New booklet* describes uniform case hardening up to .150" with controlled carburizing baths. American Cyanamid & Chemical Corp. Bulletin 372.

*New book "Hardness"* describes and evaluates hardness research of noted pioneers, methods of testing and testing instruments. Nitralloy Corp. Bulletin 366.

*Four basic heat treating* atmospheres are described in new booklet by Westinghouse. Bulletin 383.

*"Heat Treating Topics"* is title of new bulletin of special interest to heat treaters, issued by Rex & Er... Bulletin 424.

*Vapocarb-Hump method* for heat treatment of steel is the title of newly-revised catalog issued by Leeds & Northrup. Bulletin 453.

*The complete line* of heat treating furnaces, burners and other equipment of this company is described and illustrated in new bulletin "D" just issued. Eclipse Fuel Engineering Co. Bulletin 483.

Use Handy Coupon on Page 164 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 164, 166, 168, 170, 172, 174, 17[illegible] 178, 180, 184, 186, 188, 190 and 19[illegible]

# *WHAT'S NEW*

## IN MANUFACTURERS' LITERATURE

*Thirty-two-page booklet,* "Production Data," presents several articles from "The Houghton Line." E. F. Houghton & Co. Bulletin 475.

*112 pages packed solid* with down-to-earth data on industrial combustion and heat practice. Hauck Mfg. Co. Bulletin 477.

*A new technical bulletin* gives information on Calliflex Bi-metal. Callite Tungsten Corp. Bulletin 478.

*Aero Heat Exchangers* for the constant and accurate control of temperature in liquids or gases are described in this 4-page leaflet by Niagara Blower Co. Bulletin 516.



*Gas-fired tool room furnaces* an pot furnaces are described in thes two booklets by Bellevue Industri Furnace Co. Bulletin 522.

*Interesting 20-page booklet* con tains extensive heat treating info mation, including a glossary of term table of weights of square and roun bars and a hardness conversio table. Pittsburgh Commercial He Treating Co. Bulletin 509.

*Heat treatment* of steel wire an furnaces used are discussed in th leaflet by Surface Combustion. Bull tin 523.

*Merits and economy* of pulverize coal firing for metallurgical furnace are discussed in this bulletin by Bab cock & Wilcox Co. Bulletin 530.

### REFRACTORIES & INSULATION

*Insulating firebrick.* Babcock Wilcox Co. Bulletin 162.

*Heavy Duty Refractories.* Norto Co. Bulletin 164.

*Conductivity* and heat transfe charts. Johns-Manville. Bulletin 16

*D-E insulating materials* and thei application are described in ne data booklet by Armstrong Cork C Bulletin 208.

*Zircon refractories* in aluminu open hearth furnaces. Chas. Taylo Sons Co. Bulletin 347.

*"Gunmix"*, a new series of refrac tories designed for rapid emplace ment by air stream and water, described and illustrated. Basi Refractories, Inc. Bulletin 480.

*Steel Plant Cement* for hot or co patching of soaking pits, ope hearths, electric furnaces, forgi furnaces and reheating furnaces described in new folder by Electr Refractories & Alloys Corp. Bulleti 407.

*"Carbofrax"* refractory skid rai are described and blueprinted fo many types of furnaces in thi 20-page booklet by the Carborundu Co. Bulletin 500.

*Wesgo super refractory shapes* ar described in this bulletin. Wit ability to withstand almost an amount of thermal abuse, thes shapes possess high fusing range (u to 3100 deg. F.), low thermal con ductivity and complete freedo from impurities such as iron. West ern Gold and Platinum Works. Bu letin 526.


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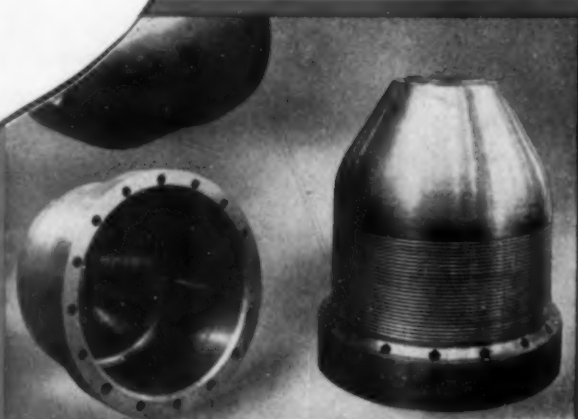



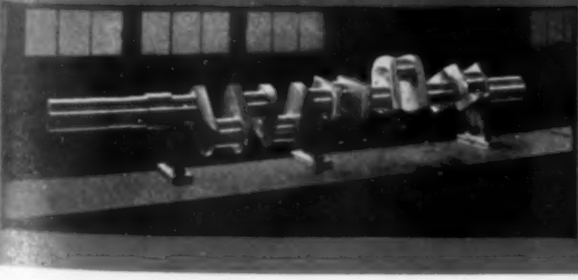

# *WHAT'S NEW*

## IN MANUFACTURERS' LITERATURE

### FINISHING • PLATING • CLEANING

*Roto-Finish equipment* for deburring, buffing, polishing and coloring. Sturgis Products Co. Bulletin 170.

*A protective, deep black finish* to steel. Heatbath Corp. Bulletin 171.

*Alvey Ferguson Co.* shows how various product washing problems were solved. Bulletin 172.

*Motor-Generators* for electroplating and other electrolytic processes. Columbia Electric Mfg. Co. Bulletin 173.

*Detrex metal cleaning machines*, metal cleaning chemicals and processing equipment. Detrex Corporation. Bulletin 175.

*Airless Rotoblast.* Pangborn Corp. Bulletin 176.

*Rust inhibiting* wax coatings for protection of metal. S. C. Johnson & Son, Inc. Bulletin 180.

*Cadmium Plating.* E. I. duPont deNemours & Co., Inc. Bulletin 177.

*Tumbling and cleaning.* Globe Stamping and Machine Co. Bulletin 179.

*Catalog* on finishing and cleaning. Frederick Gumm Chemical Co., Inc. Bulletin 292.

*"Indium and Indium Plating".* Indium Corp. of America. Bulletin 182.

*Jetal process* and its characteristics as a protective coating. Alrose Chemical Co. Bulletin 213.

*Cyanide zinc and bright zinc* plating with Turco Type X, Turco Porokleen and Turco Penetrol is described in this 10-page booklet by Turco Products, Inc. Bulletin 495.

*Special data sheets* on compounds for various cleaning jobs are offered by MacDermid, Inc. Bulletin 436.

*Technical bulletin* describes materials developed to meet specialized processing and cleaning needs. Kelite Products, Inc. Bulletin 438.

*"Deoxidine"* for a better rust removing and metal cleaning job is described along with several applications in this 4-page leaflet. American Chemical Paint Co. Bulletin 528.

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# *WHAT'S NEW*

**IN MANUFACTURERS' LITERATUR**

*Several practical* data sheets sho cleaning methods used on aluminum brass and steel. Diversey Corp Bulletin 446.

*"Surface-Peening"* by shot-blastin to improve the strength of meta parts is described in this leaflet b W. W. Sly Mfg. Co. Bulletin 521.

## ENGINEERING • APPLICA TIONS • PARTS

*Carburizing Boxes.* Pressed Stee Co. Bulletin 193.

*Chace manganese alloy No. 772* i sheets, strips, rod and special shape described by W. M. Chace Co. Bul letin 190.

*Heat treating fixtures* for pit-typ furnaces are shown in new bookle by Driver-Harris Co. Bulletin 363.

*Pressed steel pots* are described b Bell & Gossett Co. in new Bulleti 364.

*New 32-page illustrated* bookle contains much data on manganes steel for the railroad industry American Manganese Steel Div. Bul letin 388.

*Illustrated leaflet* presents data an uses of special alloys resisting cor rosion, high temperatures and abra sion. The Duraloy Co. Bulletin 390

*New information sheets* on tapere and formed tubes have just bee issued by Summerill Tubing Co. Bul letin 369.

*54-page booklet,* "File 41 — Engi neering Data Sheets", gives complet facts on Ampco Metal's physica properties and service record. Bul letin 368.

*Many applications and saving* through use of drop forgings ar shown in Drop Forging Topics issued by Drop Forging Assn. Bul letin 240.

*Electrical,* corrosion and heat re sisting alloys in rod, wire, ribbon and strip forms. Wilbur B. Driver Co. Bulletin 192.

*Catalog* gives complete specifica tion data on Bunting bearings and bars. Bunting Brass & Bronze Co. Bulletin 343.

*Specifications and physical* prop erties of bronze and aluminum alloys are shown in Olds Alloys Co. Bulle tin 457.


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# WHAT'S NEW

## IN MANUFACTURERS' LITERATURE

*Reference data book* entitled "The Improvement of Metals by Forging" has been issued by Steel Improvement & Forge Co. Bulletin 409.

*Interesting* and informative literature on "Pomet" powder metallurgy products. Powder Metallurgy Corp. Bulletin 454.

*Industrial applications* of National and Karbate carbon and graphite products are illustrated in 16-page booklet issued by National Carbon Co., Inc. Bulletin 426.

*24-page catalog* is guide to properties and use of Monsanto plastics. Monsanto Chemical Co. Bulletin 319.



*X-Ray Inspected Castings.* Elect Alloys Co. Bulletin 197.

*Steel Castings.* Chicago Steel Fou dry Co. Bulletin 199.

*Heat Resisting Alloys.* General loys Co. Bulletin 200.

*Pipes and Tubes.* Michigan St Casting Co. Bulletin 201.

*Cr-Ni-Mo Steels.* A Finkl & So Co. Bulletin 203.

*Industrial baskets,* crates, trays a fixtures. Rolock, Inc. Bulletin 20

*Handsome 12-page brochure* pi tures the cast steel breech rings a their advantages as produced by t Ohio Steel Foundry Co. Bulletin 51

*Many types of heat treating* a pickling baskets and containers a shown in new booklet by the Sta wood Corp. Bulletin 445.

*Complete line of Mallory* radi electrical and electronic parts, wi sizes, dimensions and rated capa ities is described in new 36-pa booklet. P. R. Mallory & Co., In Bulletin 448.

*The Wilco Blue Book* deals wi the 29 Wilco Thermometals, the properties, functions, applicatio and temperature ranges. H. A. Wi son Co. Bulletin 531.

*Illustrated leaflet* describes stai less steel castings by Atlas Foundr Co. Bulletin 437.

*Illustrating* several heat resista alloy applications, this 4-page leafl cites four factors essential to eff cient alloy use. Sterling Alloys, In Bulletin 504.

*Cooper standard alloys.* Coope Alloy Foundry Co. Bulletin 206.

*Three-color chart* of decimal equi alents. John Hassall, Inc. Bulleti 458.

*Drop, hammer and upset forgin* Kropp Forge Co. Bulletin 534.

*Steel Forgings.* Transue and Wi liams Steel Forging Co. Bulletin 53

*Specifications and diagrams* ar included in description of welde rings and bands. American Weldin & Mfg. Co. Bulletin 536.

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## *WHAT'S NEW*

**IN MANUFACTURERS' LITERATURE**

### MELTING • CASTING • MILL OPERATIONS

*Ingot Production.* Gathmann Engineering Co. Bulletin 185.

*Crucibles for brass,* copper, aluminum and magnesium industries. Electro Refractories and Alloys Corp. Bulletin 183.

*This ring-binder* presents 24 pages on the use and effect of Titanium in steel and cast irons. Titanium Alloy Mfg. Co. Bulletin 470.

*52-page booklet* describes Moore rapid Lectromelt furnaces for iron, steel, nickel and copper melting and refining. Pittsburgh Lectromelt Furnace Corp. Bulletin 404.

*"Electromet Products and Service".* Electro Metallurgical Co. Bulletin 186.

*Interesting and helpful* information available on the use of alloy pots for heating operation by the Swedish Crucible Steel Co. Bulletin 137.

*Operating Features,* capacities, charging methods of the Heroult electric furnace. American Bridge Co. Bulletin 215.

*Attractive booklet* describes growth, facilities and offers valuable alloy hints. Niagara Falls Smelting & Refining Corp. Bulletin 246.

*Foundry ovens for core baking,* mold drying and pasting are illustrated in new 4-page leaflet by Despatch Oven Co. Bulletin 510.

### GENERAL

*New leaflet* describes interoffice communication system offered by Executone Communication Systems. Bulletin 385.

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